Broadband geoacoustic matched field inversion with multi-step strategy from ASIAEX2001

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Outline

Introduction

Multi-step inversion strategy

Inversion results from ASIAEX2001 data

Introduction

MFI: complex, non-linear,multi-dimensional, multi-mode, global optimizing with many local minima

Validity: depend mainly on parameter's sensitivity on MFP objective function

Three layers parameters model

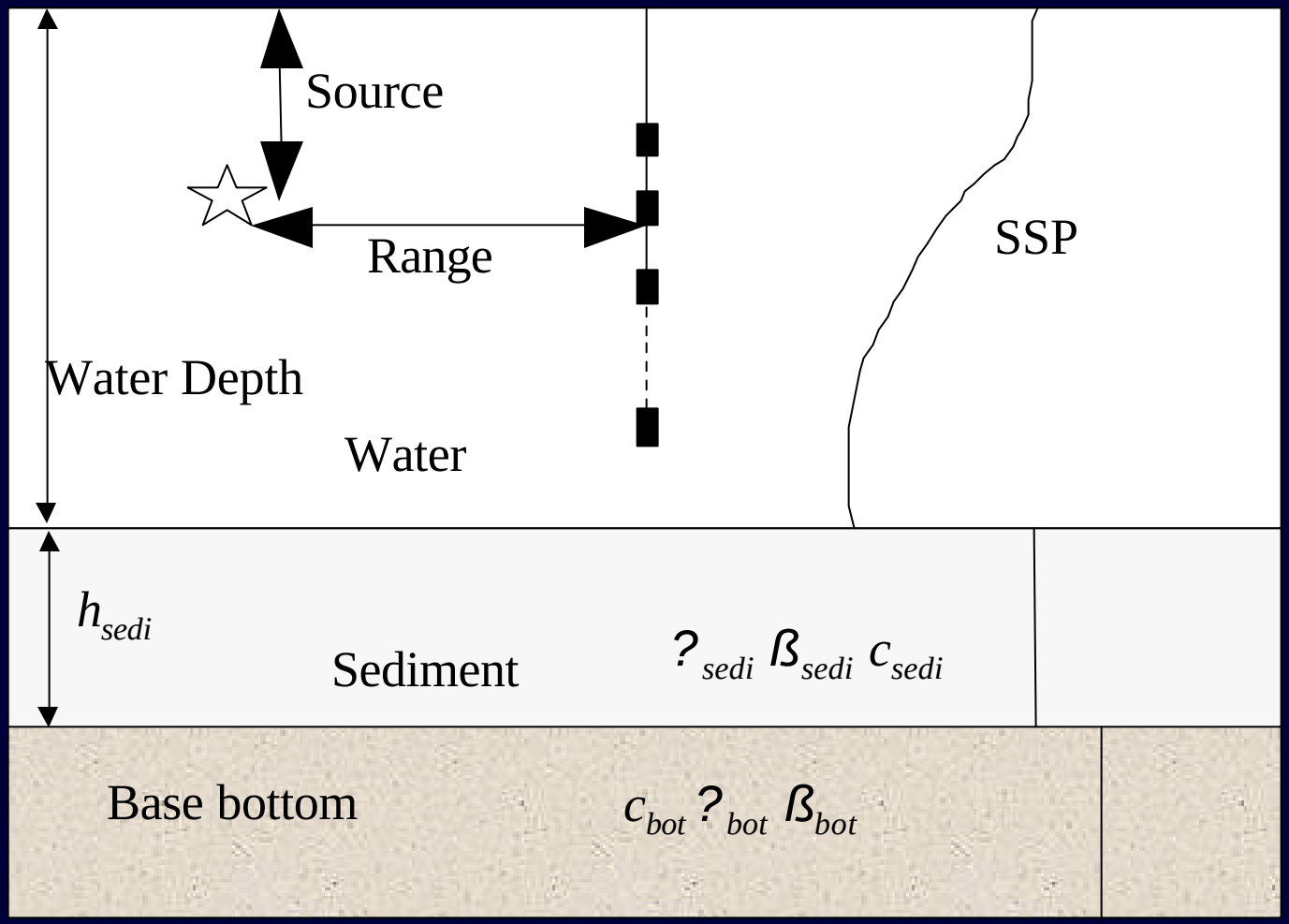
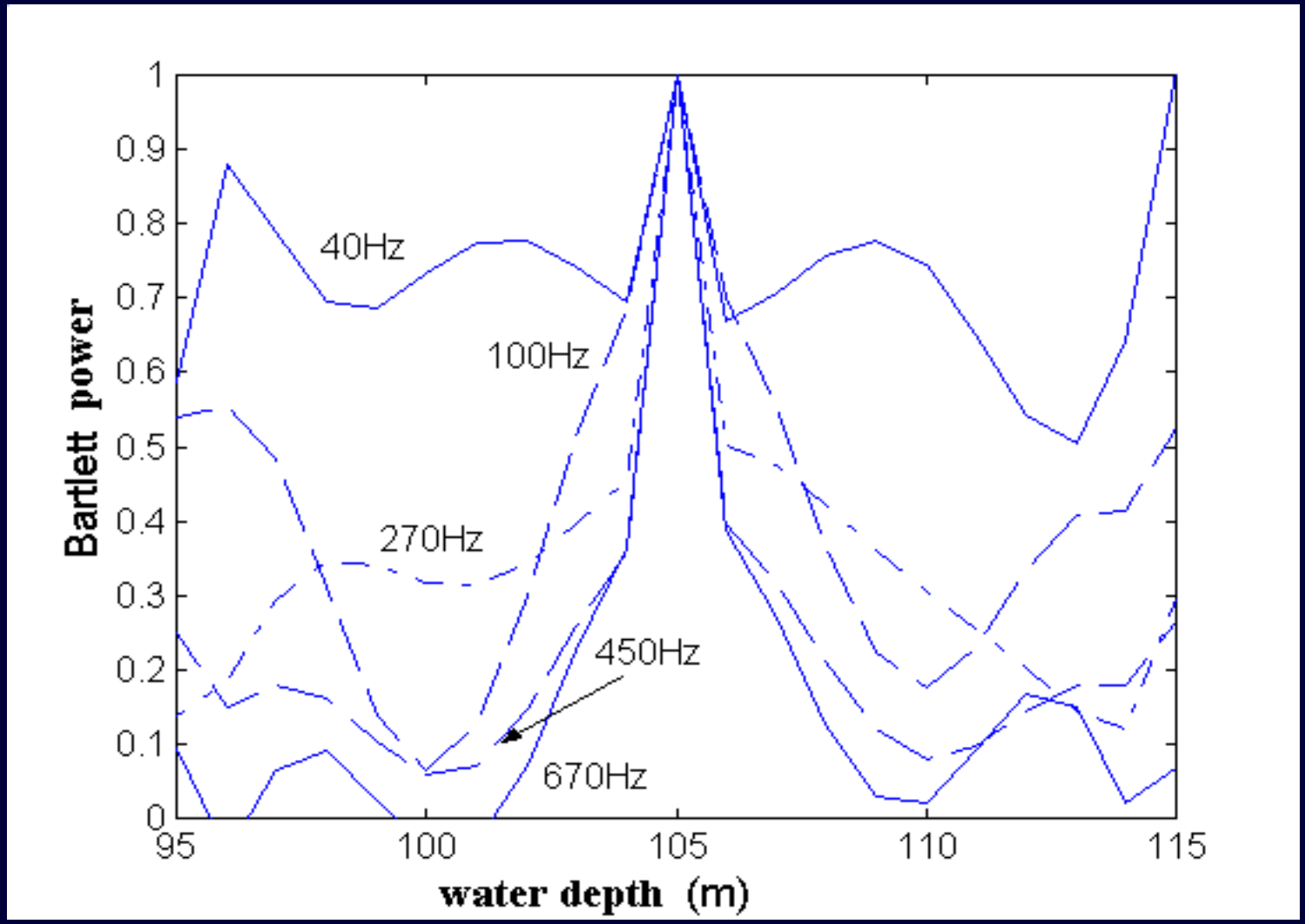
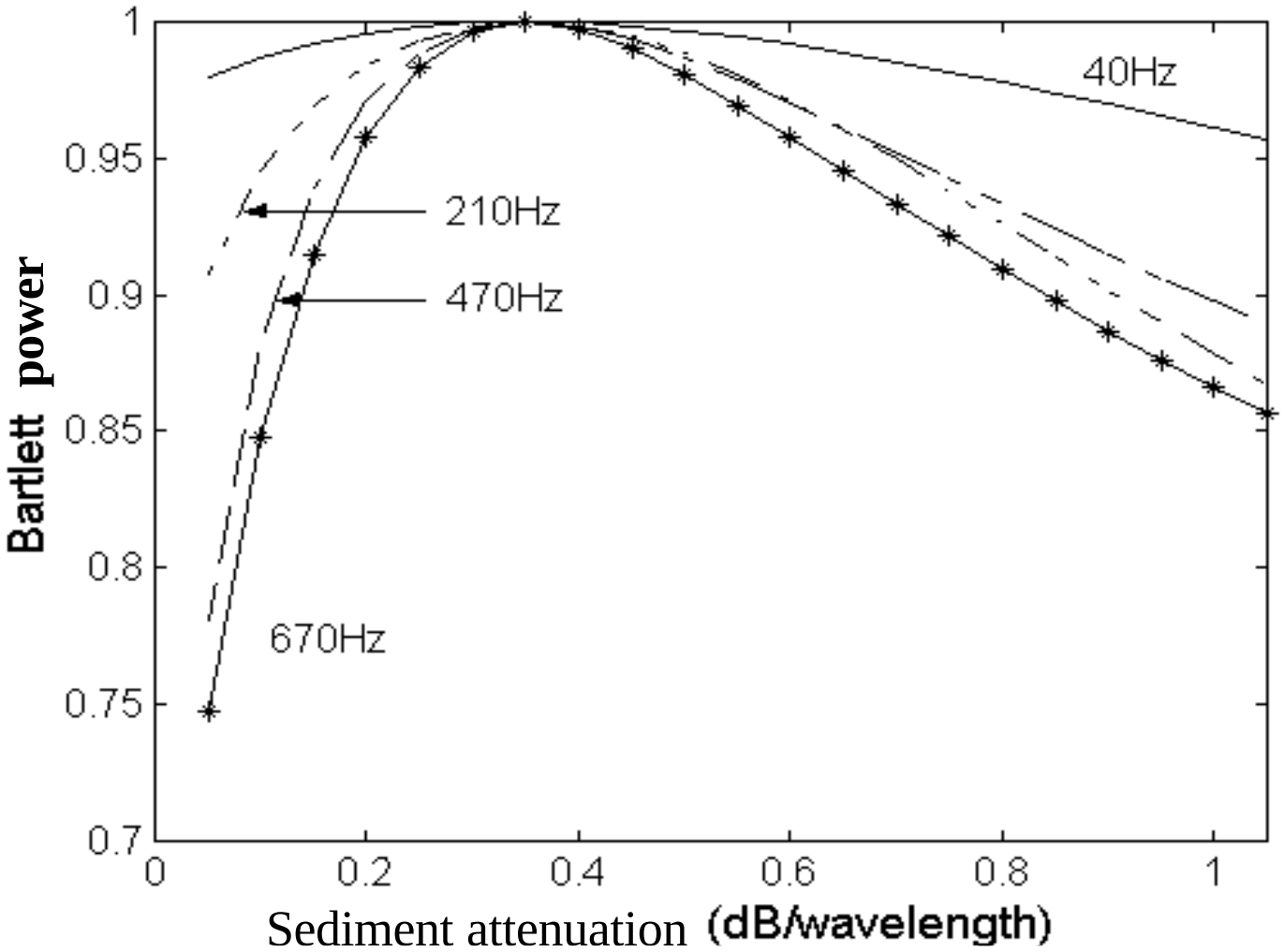


Fig.3 Parameters model

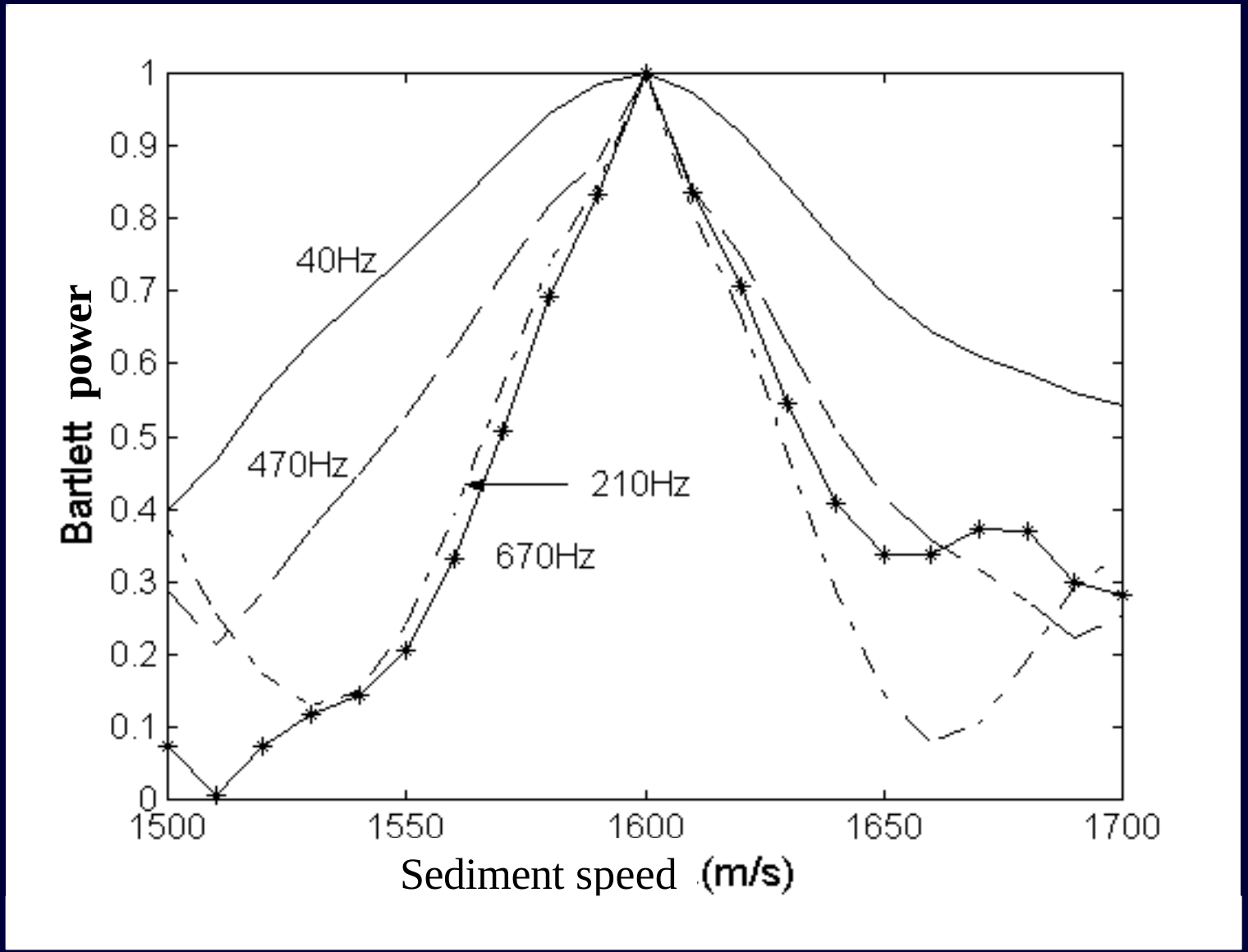
Sensitivity analysis of inverted parameters



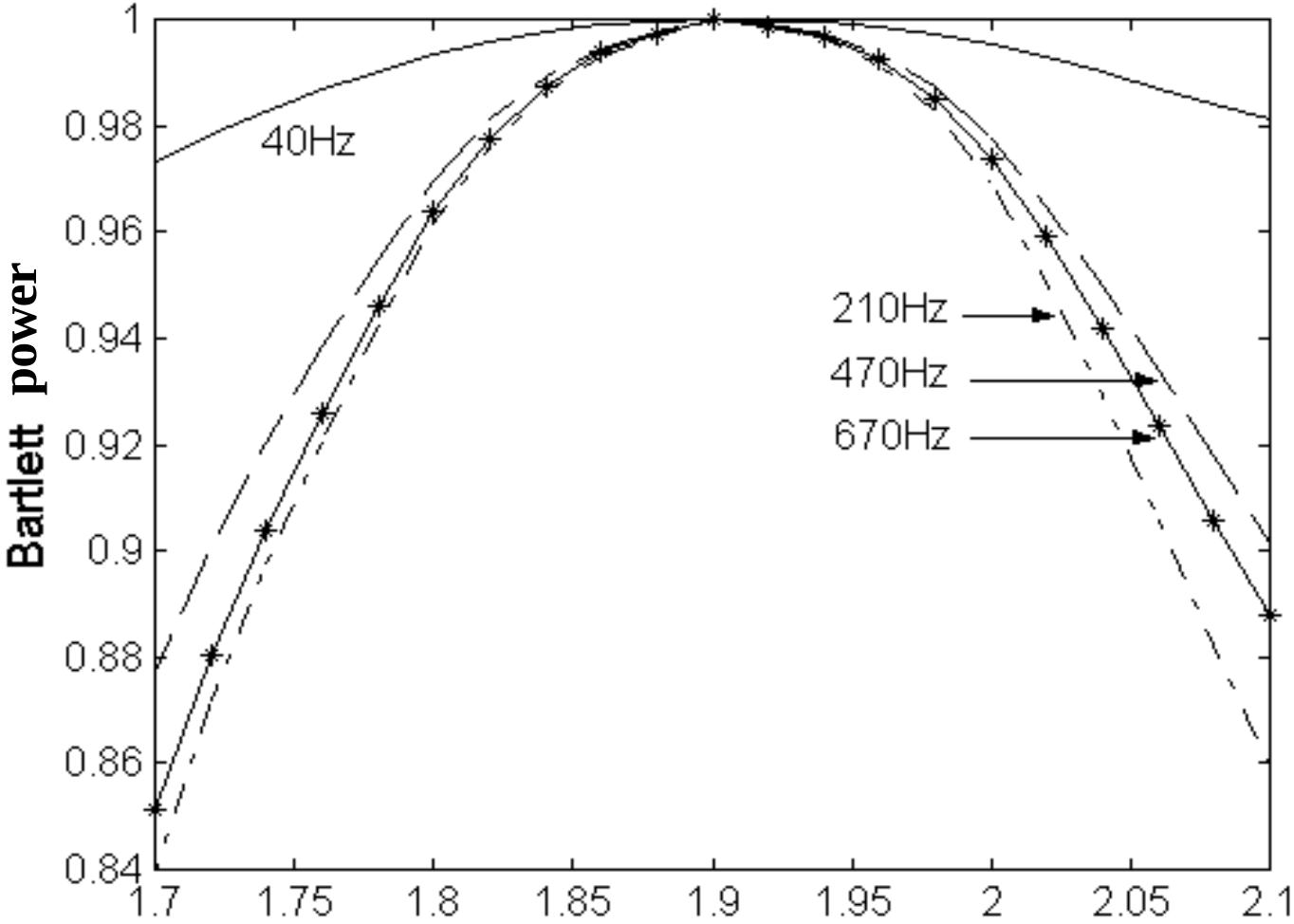
Sensitivity analysis of inverted parameters



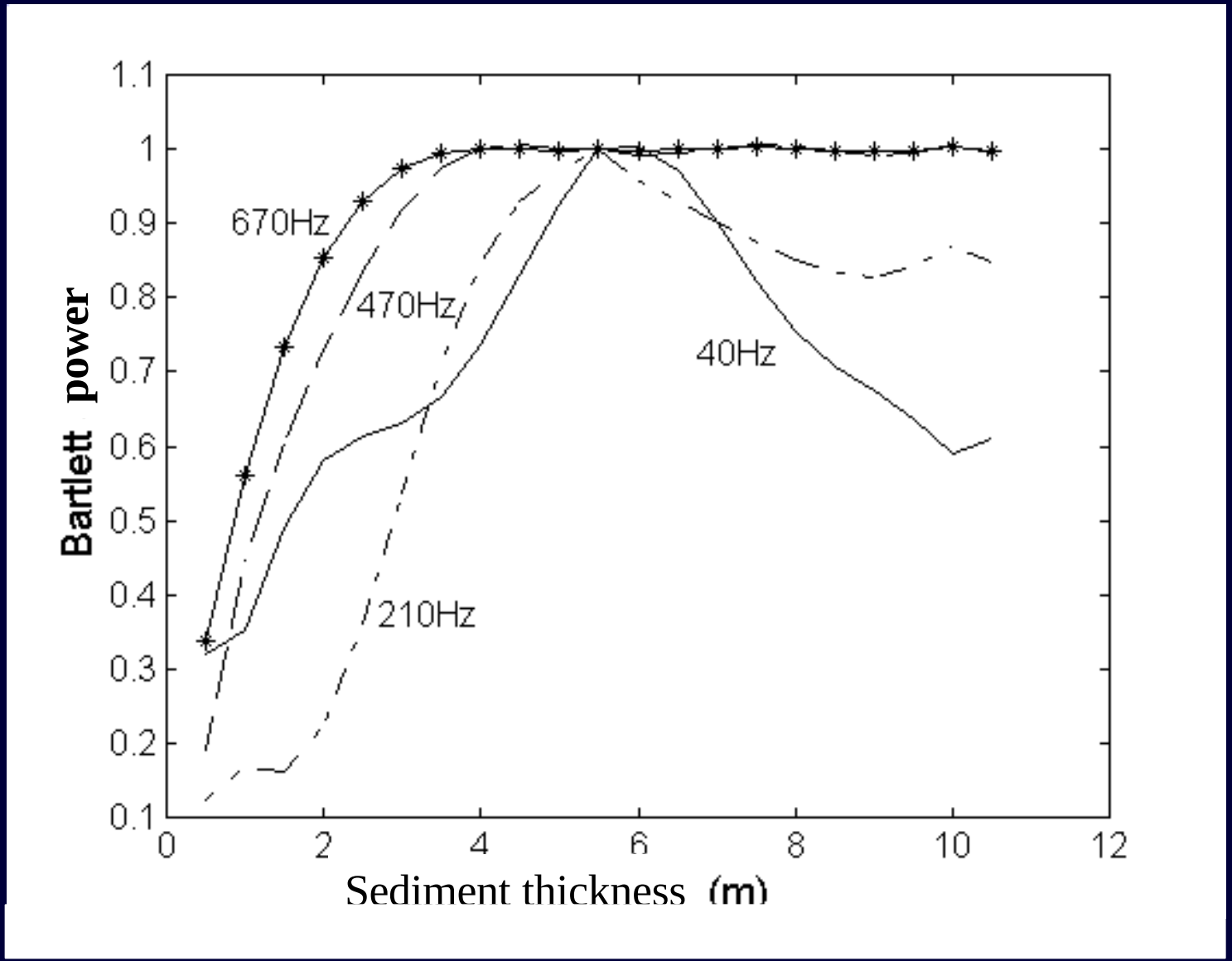
Sensitivity analysis of inverted parameters



Sensitivity analysis of inverted parameters



Sensitivity analysis of inverted parameters



Sensitivity index of inverted parameters

$$SI\ (\ f\ ) = 1 - P\ (\ f\ , S\ ) / P\ (S\ 0\ )$$

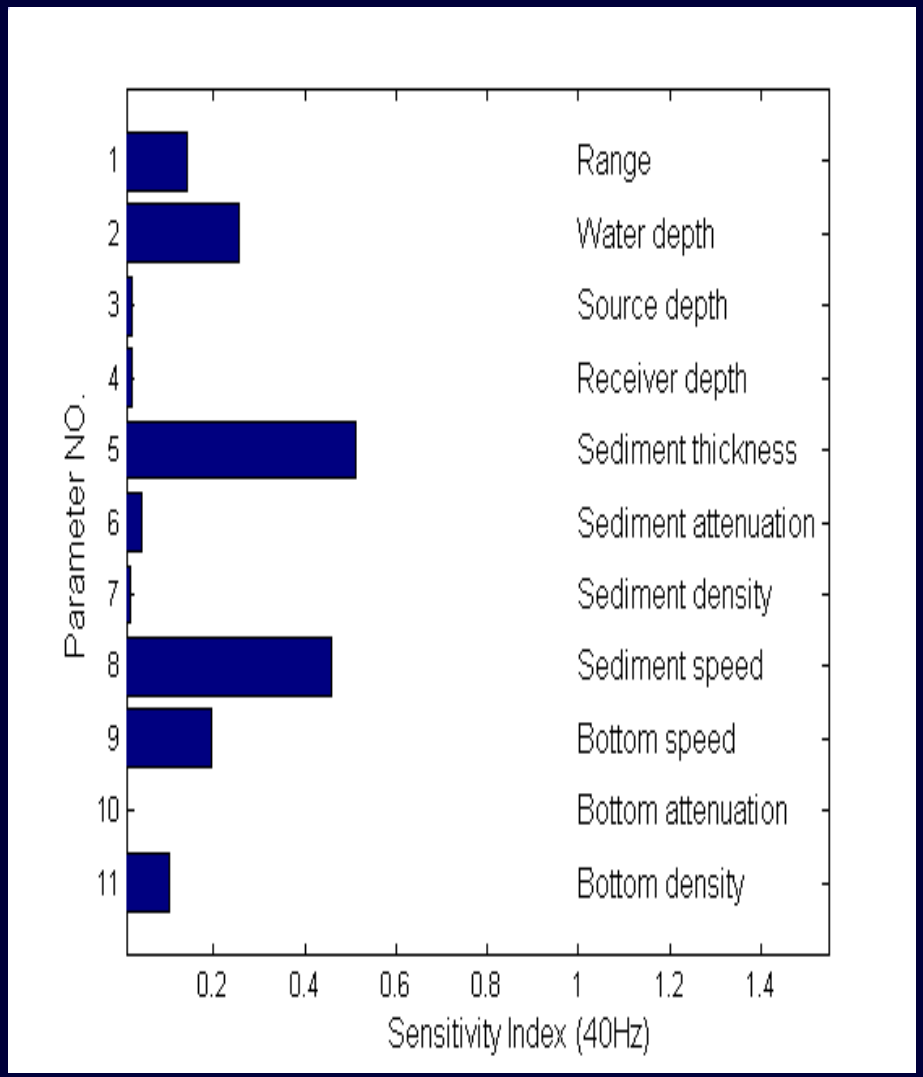
SI: sensitivity index for different frequencies

P (*S0*): MFP power for true values

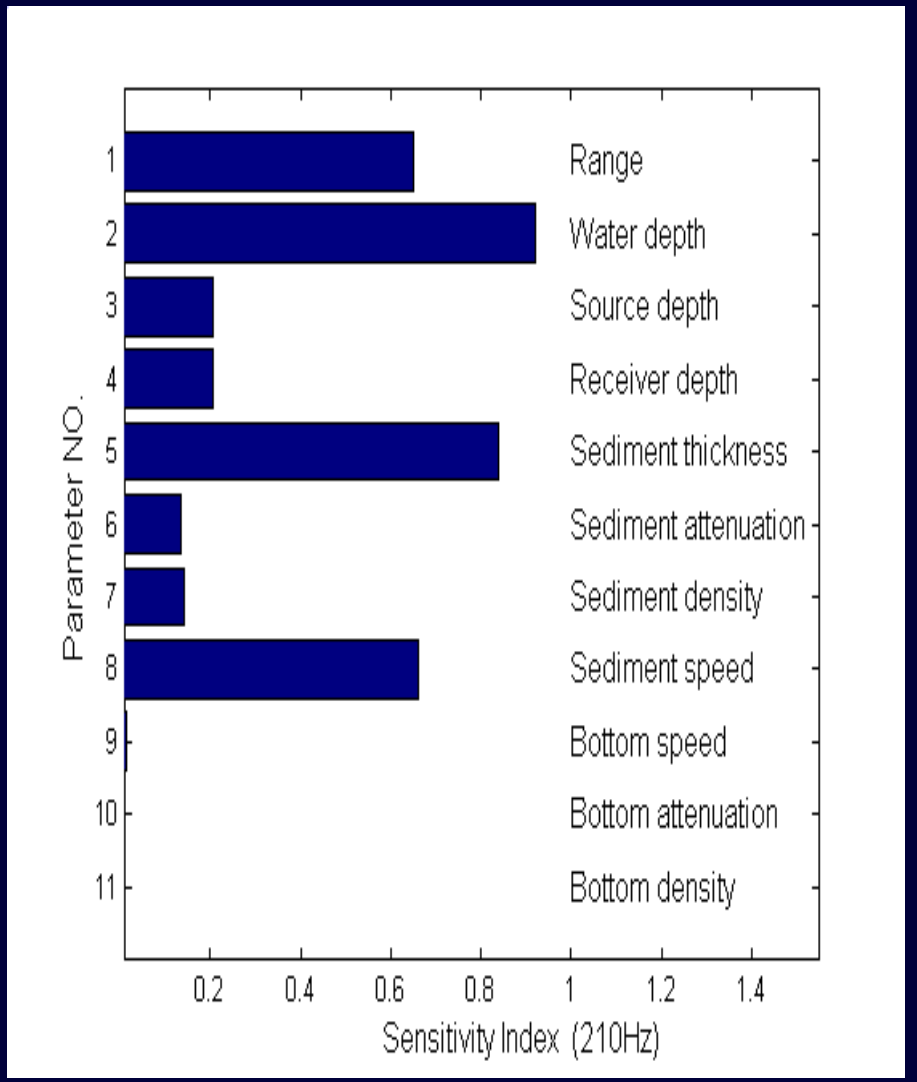
P (*f* , *S*): MFP power for boundary values in search space

SI: 0~ 1, *SI* is higher, the sensitivity is stronger

Sensitivity index of inverted parameters

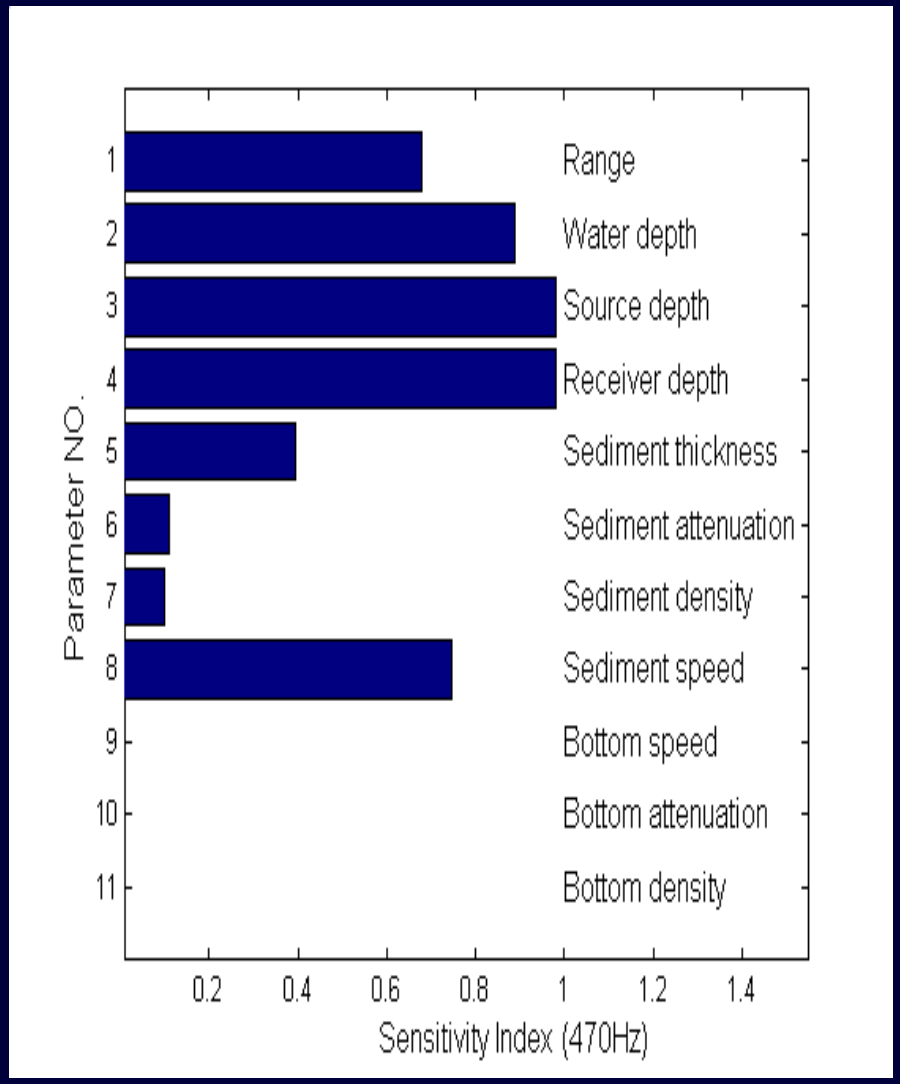


40Hz

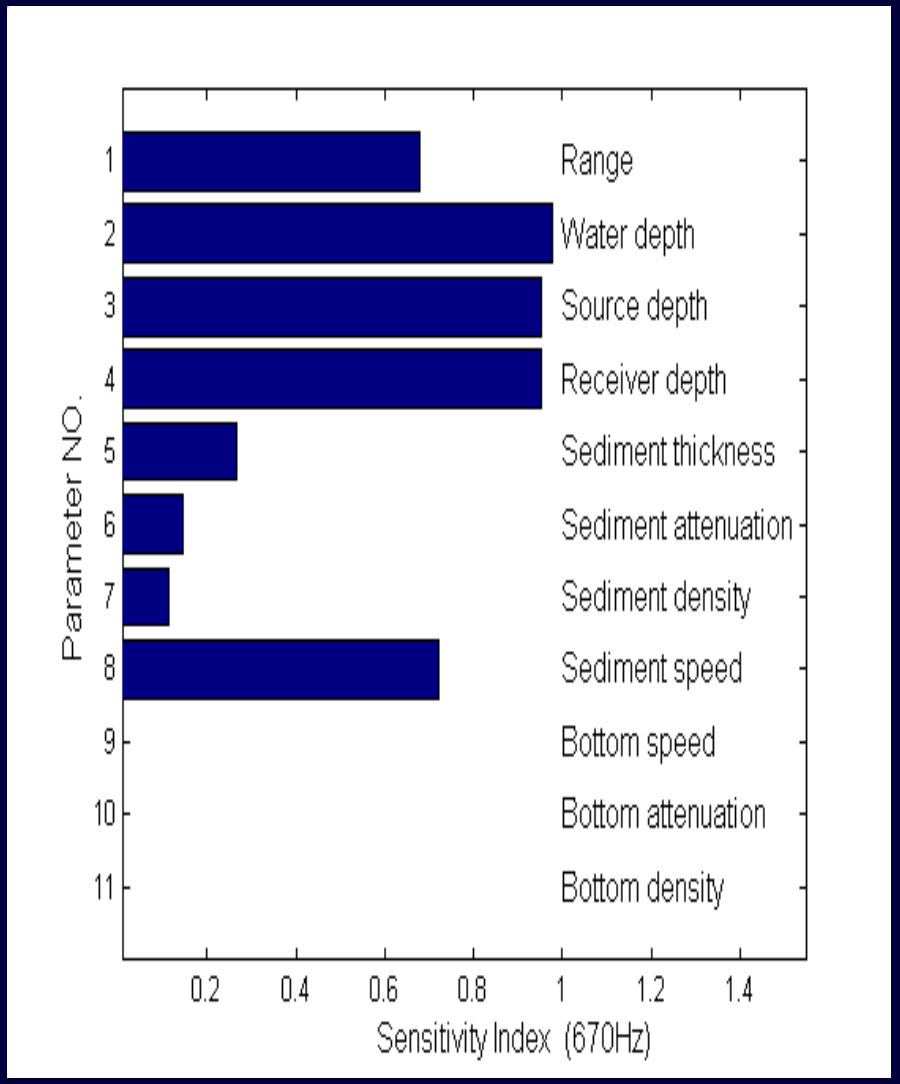


210Hz

Sensitivity index of inverted parameters



470Hz



670Hz

Sensitivity analysis of inverted parameters

(1) six parameters:

source range, source depth, water depth, receiver depth, array tilt, and sediment sound speed

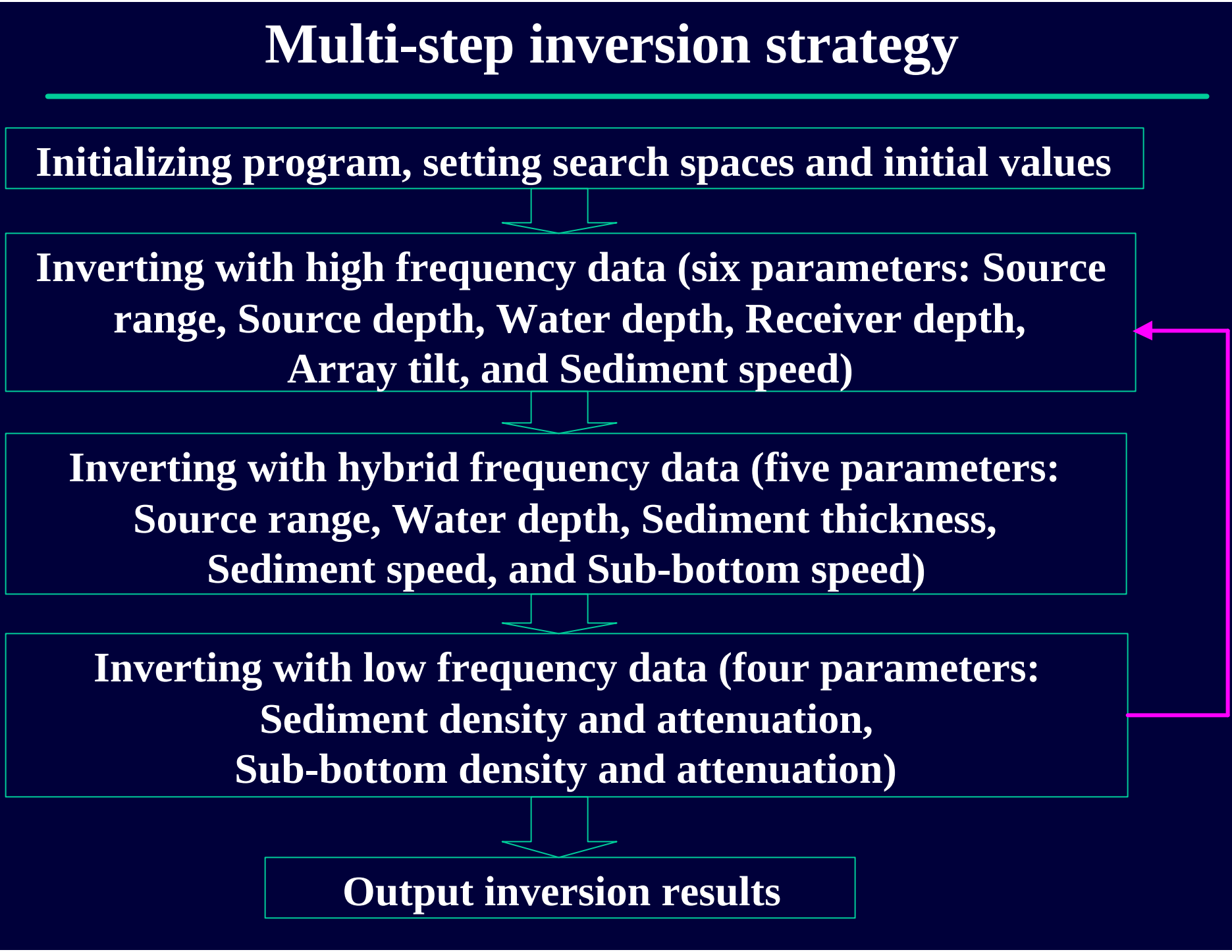
(2) two parameters:

sub-bottom speed, sediment thickness

(3) four parameters:

sediment density, sediment attenuation, sub-bottom density, and sub-bottom attenuation

Multi-step inversion strategy



Advantages of multi-step inversion compared with direct all parameters inversion

- Separating the inverted parameters into three types
- Inverting the parameters from strong to weak sensitivity
- Many unknowns (12) to multi-step operation with several unknowns (6,5,4) in each step
- The total running time for multi-step scheme is less than direct inversion.

Performance simulation for multi-step strategy

Incoherent broadband MFI objective function

$$f = 1 - \frac{1}{N_{freq}} \sum_{l=1}^{N_{freq}} \frac{\left| \mathbf{p}_l^{+} \mathbf{q}_l(\mathbf{m}) \right|^2}{\left| \mathbf{p}_l \right|^2 \left| \mathbf{q}_l(\mathbf{m}) \right|^2}$$

m: parameters vector

p: replica field vector

q: measured field vector

N_{freq}: frequency number

Performance simulation for multi-step strategy

Ten frequenciess: 30Hz, 44Hz, 55Hz, 65Hz, 74Hz, 200 Hz, 350Hz, 440Hz, 560Hz, 600Hz.

- Direct all parameters inversion: 10
- Multi-step inversion:

  First step: 350Hz, 440Hz, 560Hz, 600Hz

  Second step: 30Hz, 44Hz, 55Hz , 600Hz

  Third step: 30Hz, 44Hz, 55Hz

Performance simulation for multi-step strategy

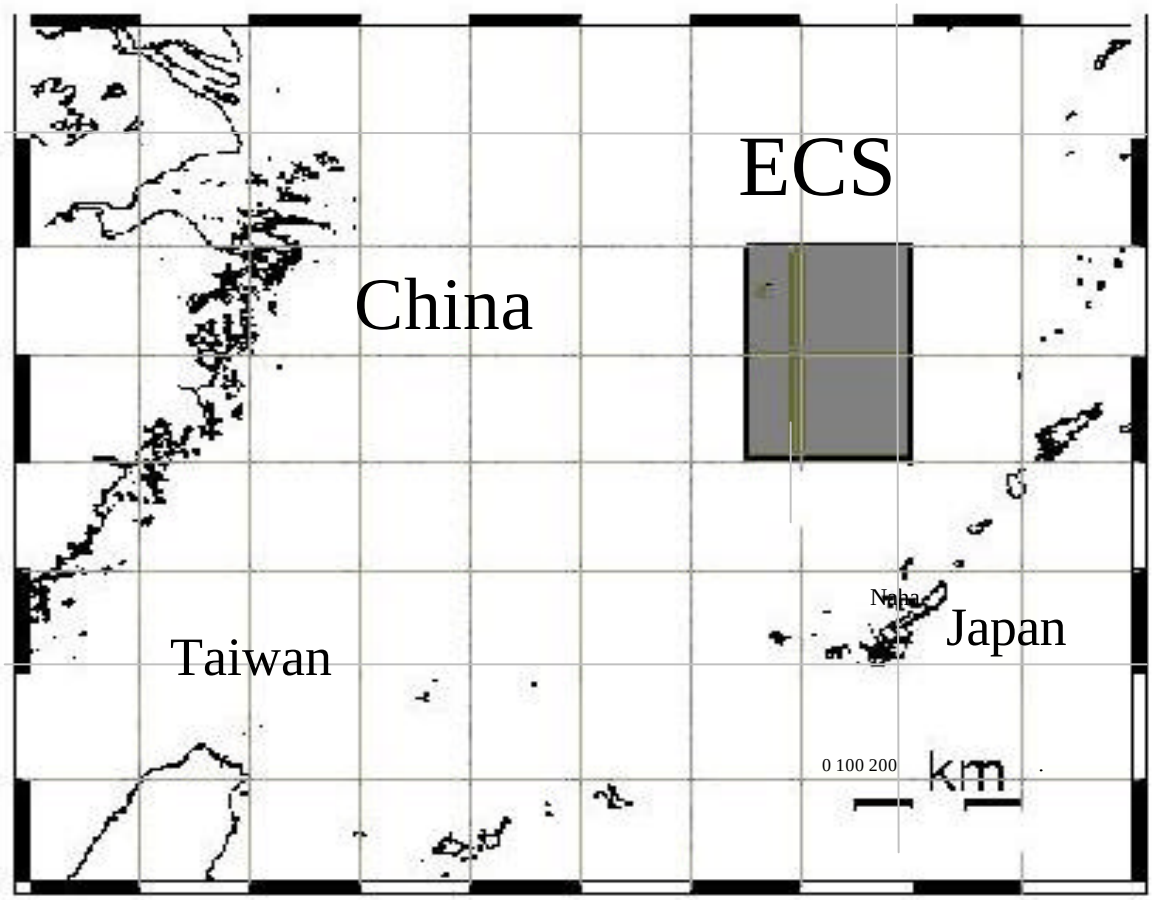
Parameters		True values	Search space	Direct inversion results	Multi-step results	Direct inversion errors	Multi-step errors
Water depth(m)		105	100-110	105.238	105.032	0.238	0.032
Range(km)		15.094	14.5-15.5	15.119	15.097	0.025	0.003
Source depth(m)		50	45-55	49.921	50.079	-0.079	0.079
Receiver depth(m)		86.6	83-89	85.762	86.619	-0.838	0.019
Array tilt (m)		0	-5-+5	0.247	0.06	0.247	0.06
Sediment	thickness(m)	5	0.5-10.0	5.627	5.024	0.627	0.024
	density(g/cm^3)	1.9	1.7-2.1	1.884	1.903	-0.016	0.03
	speed(m/s)	1640	1550-1700	1667.61	1635.714	27.619	-4.286
	attenuation(dB/?)	0.3	0.05-1.0	0.382	0.306	0.082	0.06
Sub-bottom	density(g/cm^3)	2.3	1.9-2.5	2.405	2.290	0.105	-0.01
	speed(m/s)	1900	1700-2100	1953.98	1903.175	53.968	3.175
	attenuation(dB/?)	0.3	0.05-1.0	0.623	0.291	0.323	-0.009

Performance simulation for multi-step strategy

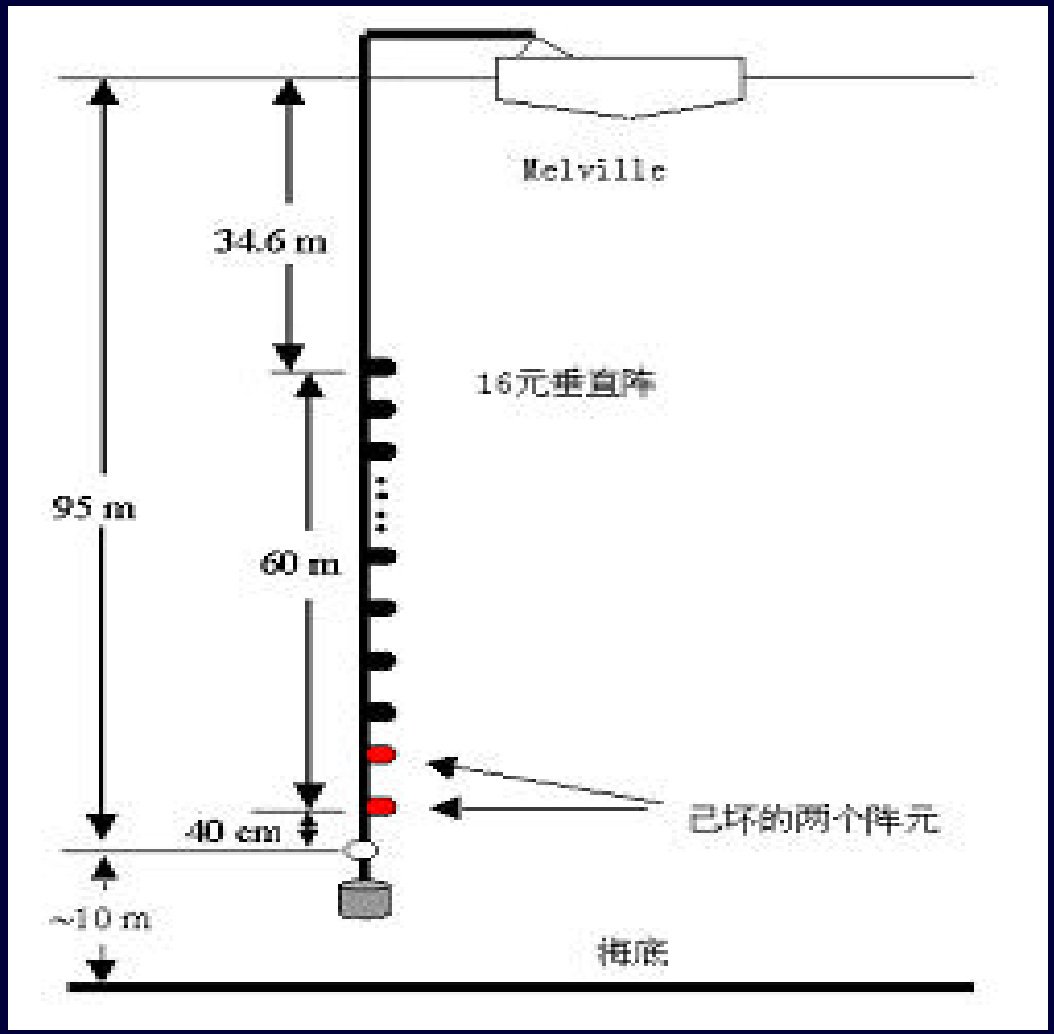
Simulation conclusion:

For multi-step strategy, the inversion errors are smaller than the direct inversion for almost all parameters.

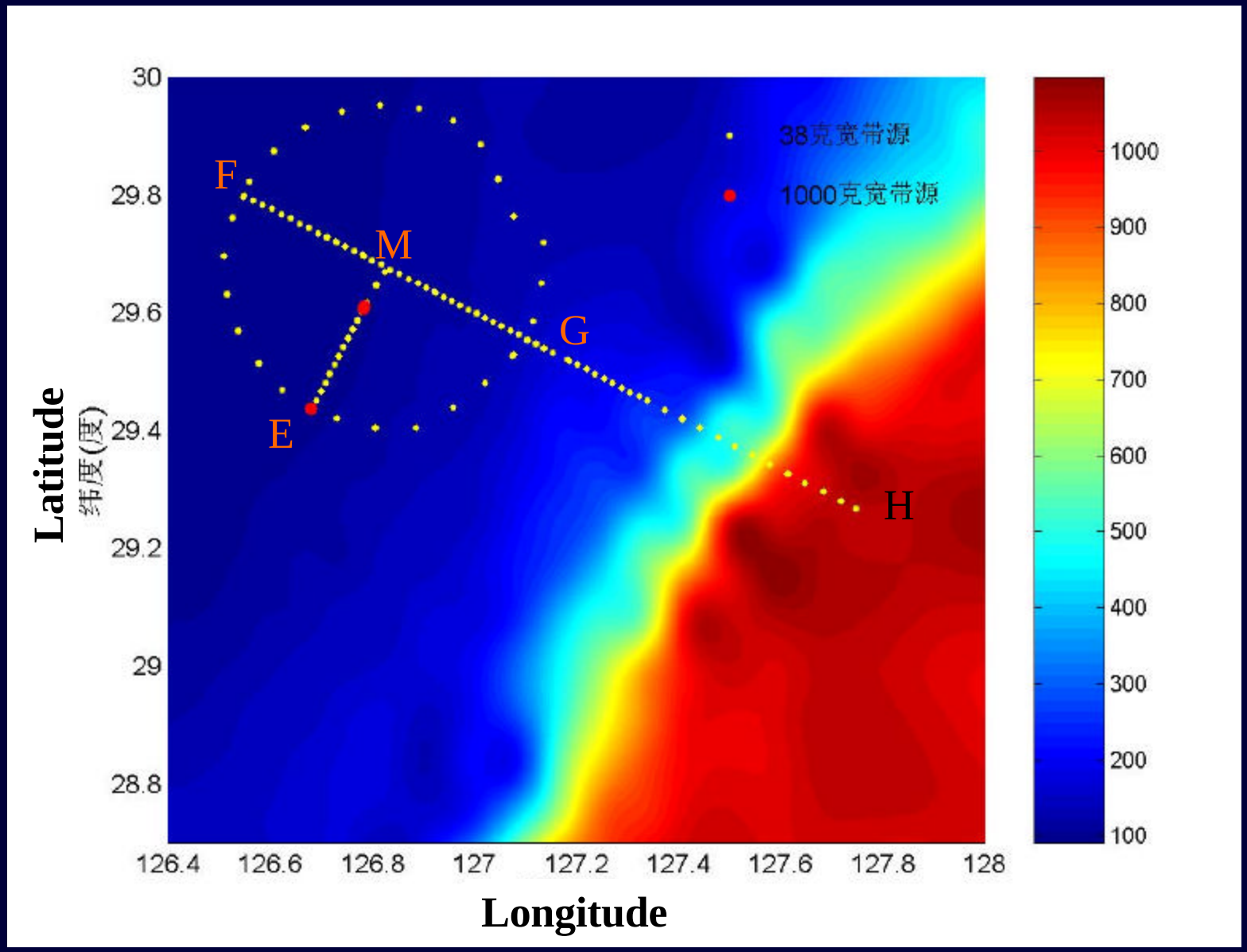
Experiment area in ASIAEX2001



Experiment area in ASIAEX2001



Trace of the explosive charges



Inversion of ASIAEX2001 in ECS

* Southwest side :ME segment,total 26 charges

  105m, flat bottom ,range-independent

* Northwest portion: near F point

  97~105m, range-dependent

* Southeast portion: near G point

  105~118m, range-dependent

Inversion of ASIAEX2001 in ECS

Replica field calculation:

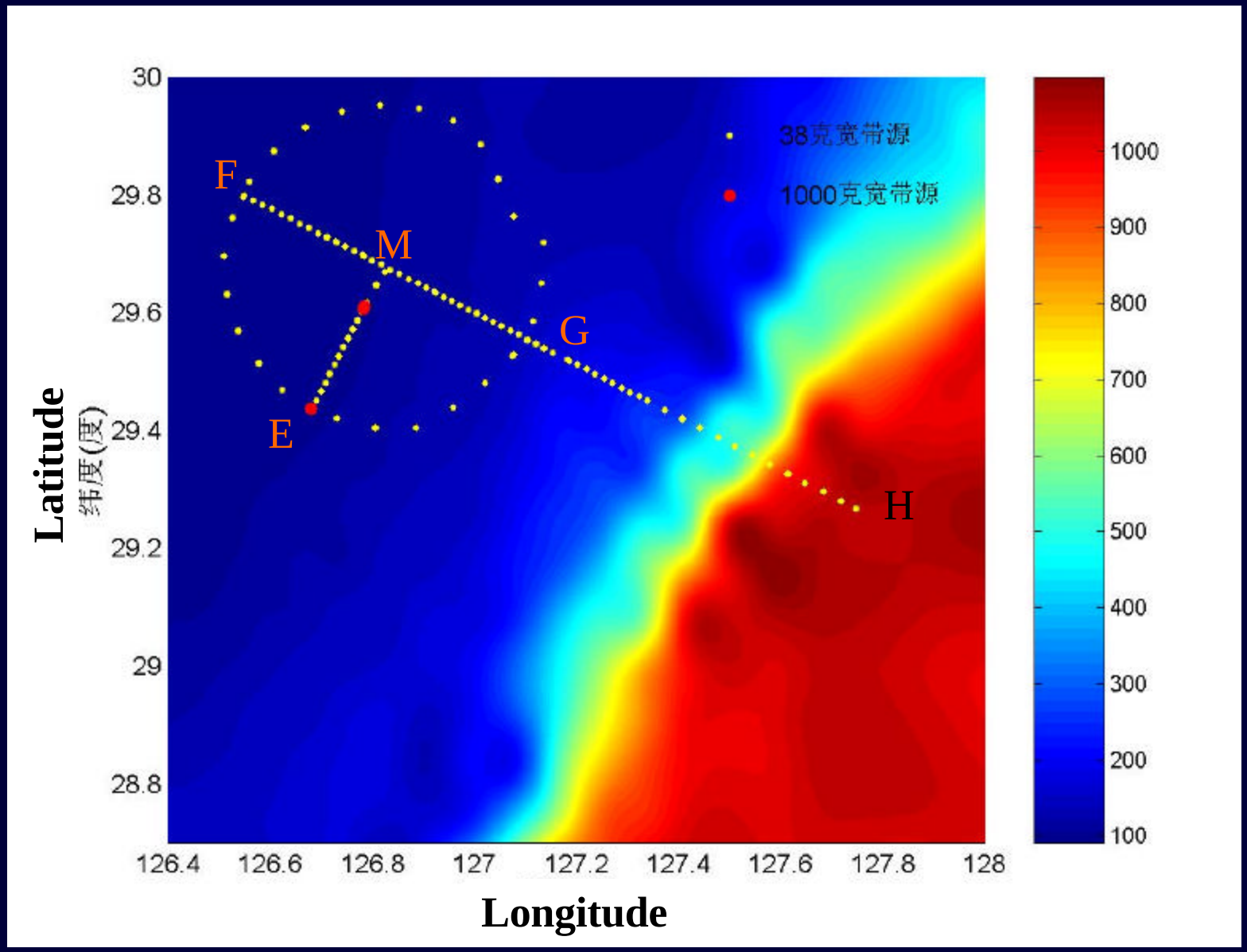
- Range-independent inversion:

  Kraken normal mode

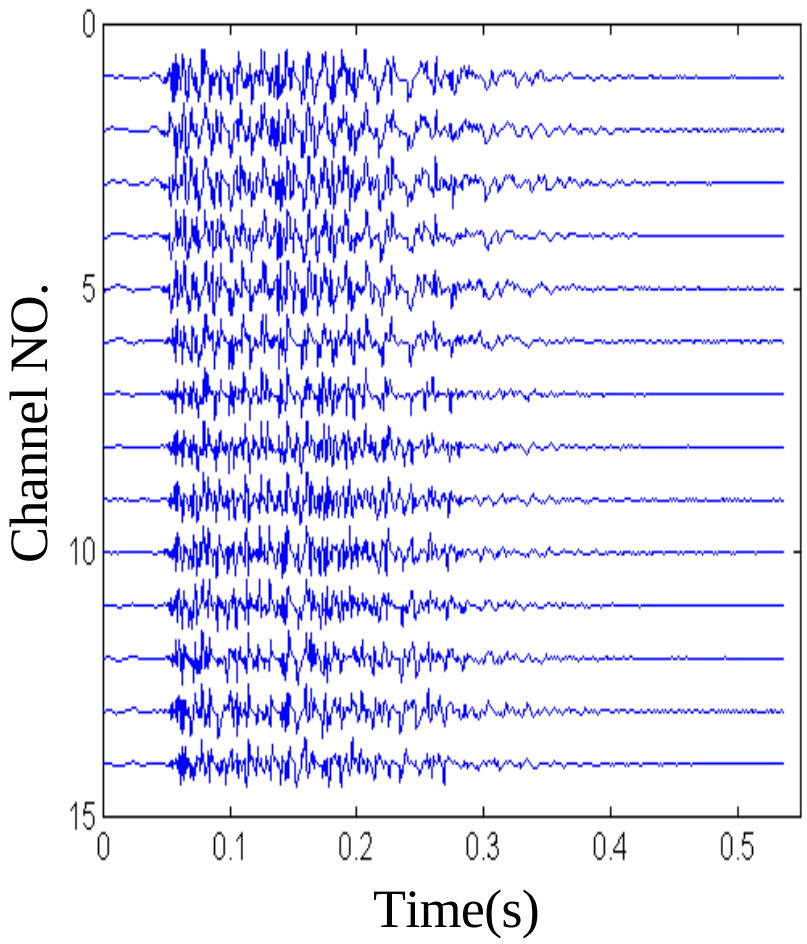
- Range-dependent inversion:

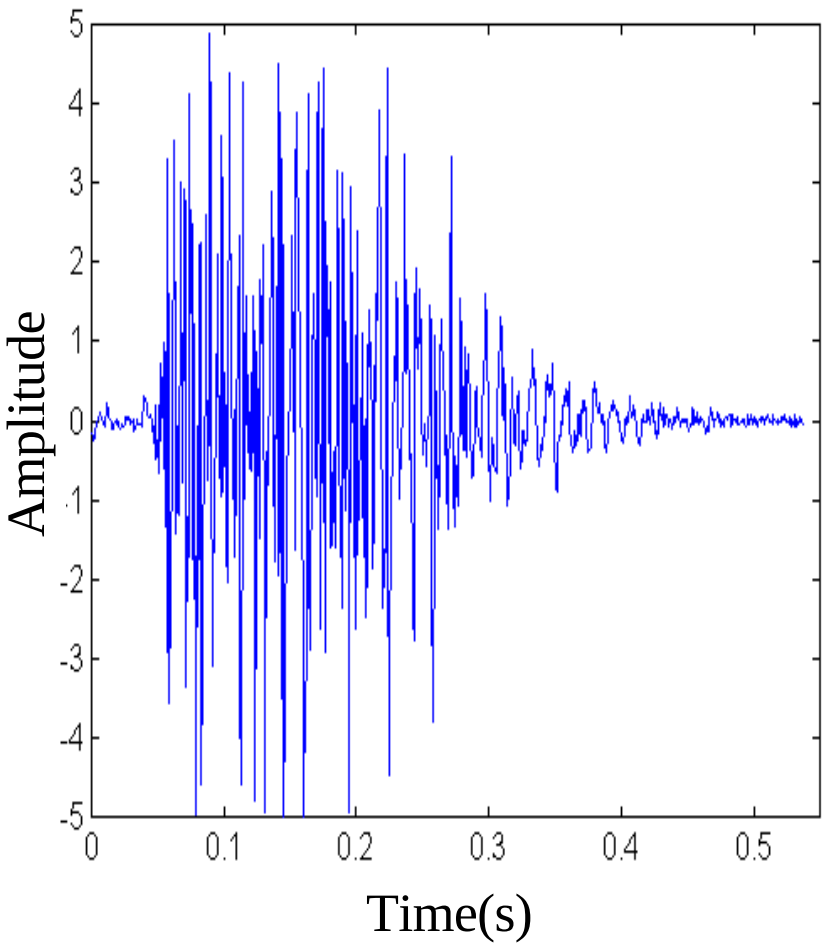
  adiabatic normal mode

Inversion of typical shot data（Shot10）



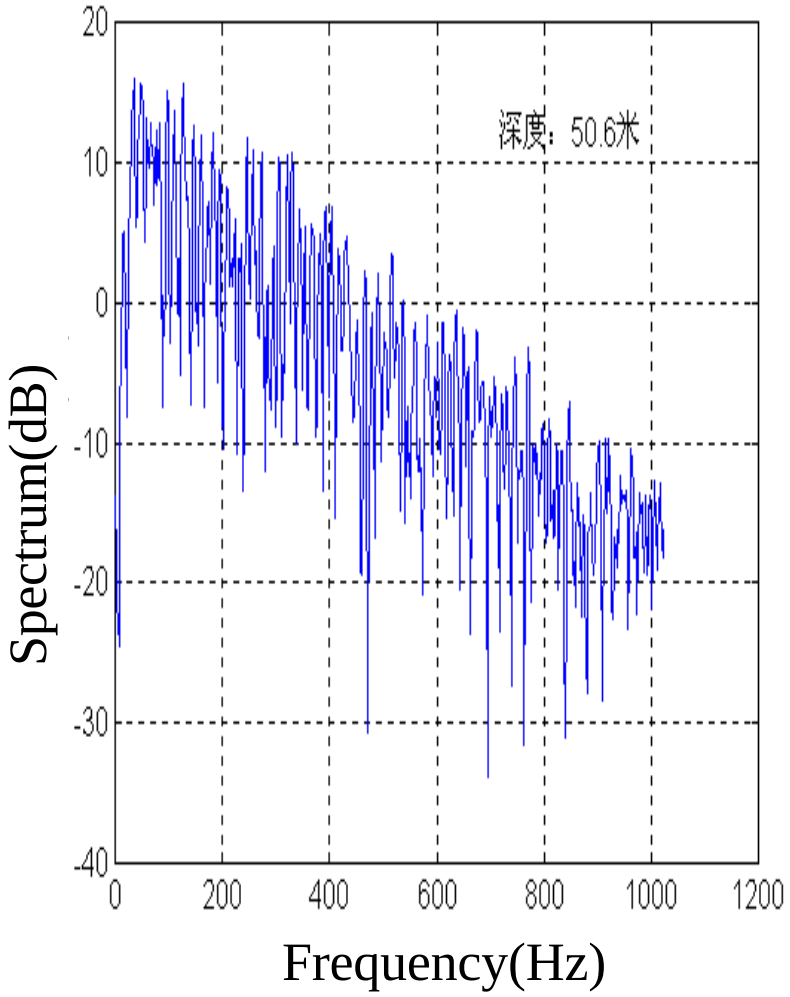
Inversion of typical shot data（Shot10）

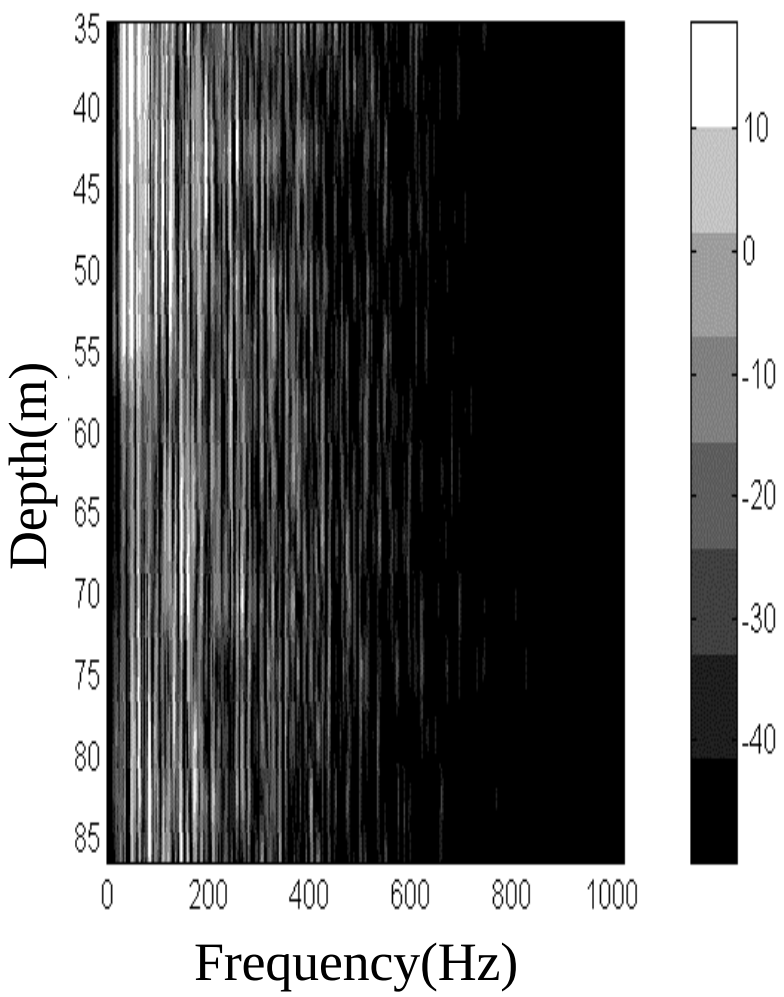




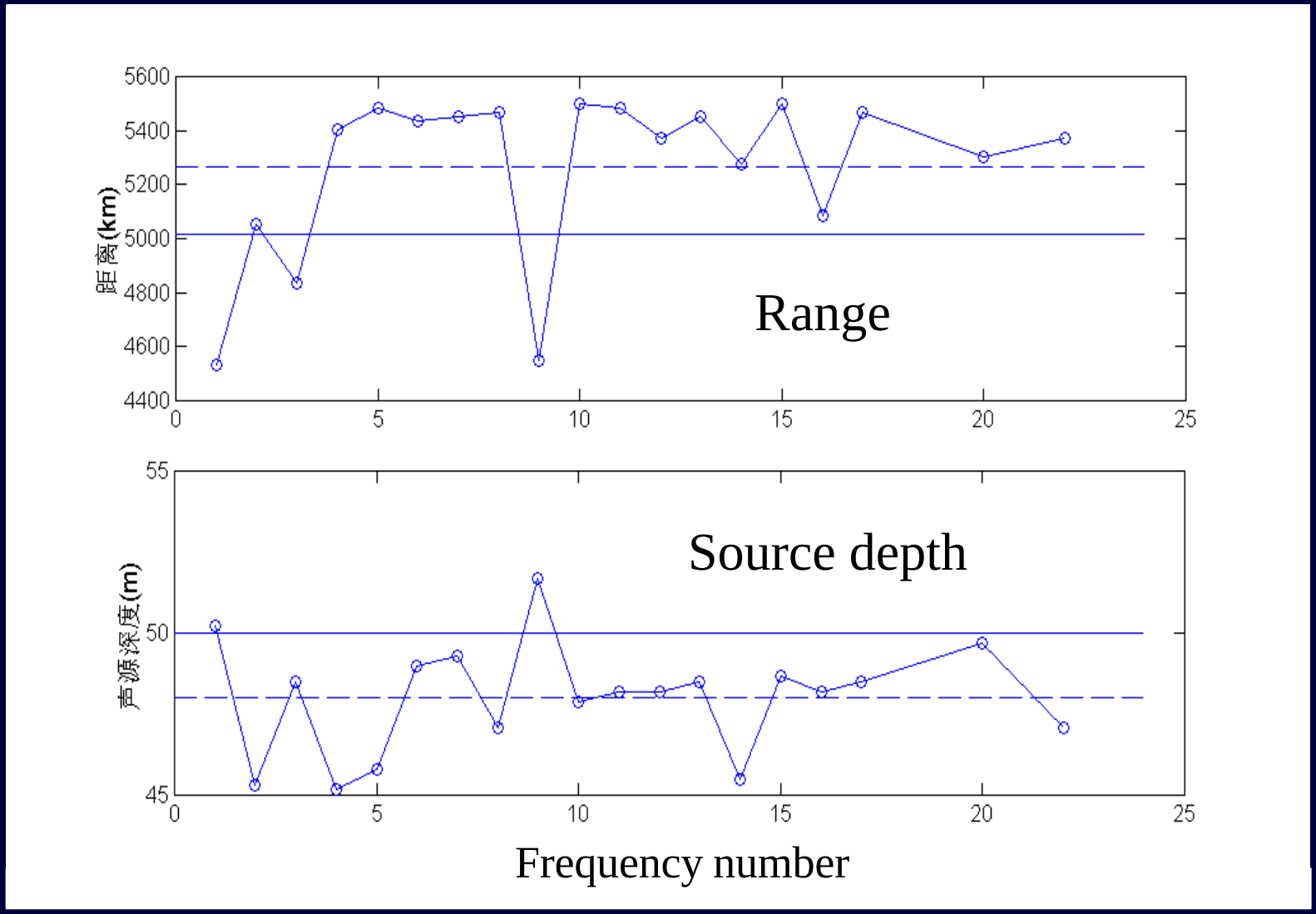
Range: 5.0179km ， Water depth: 105m, 38g-TNT

Inversion of typical shot data（Shot10）

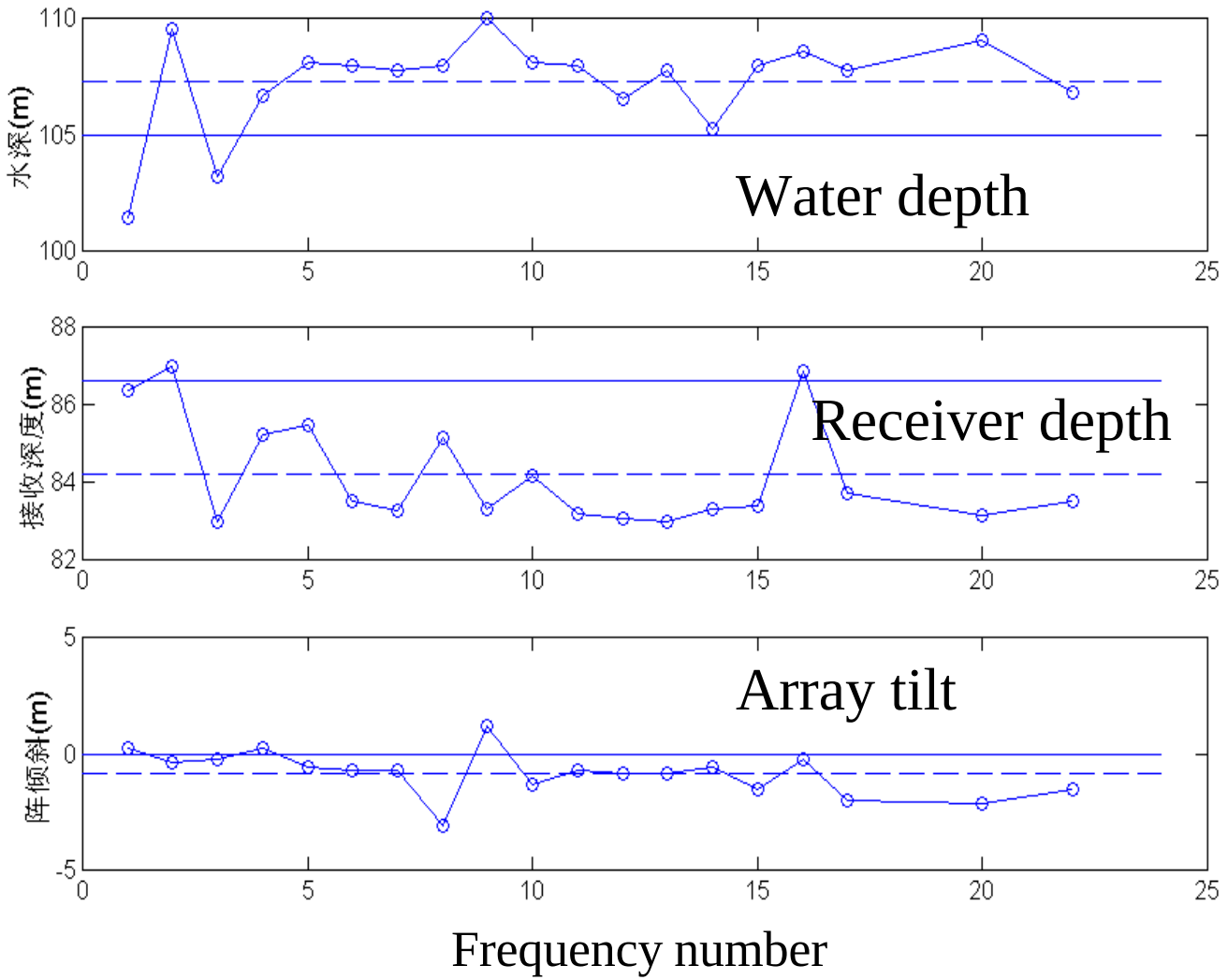




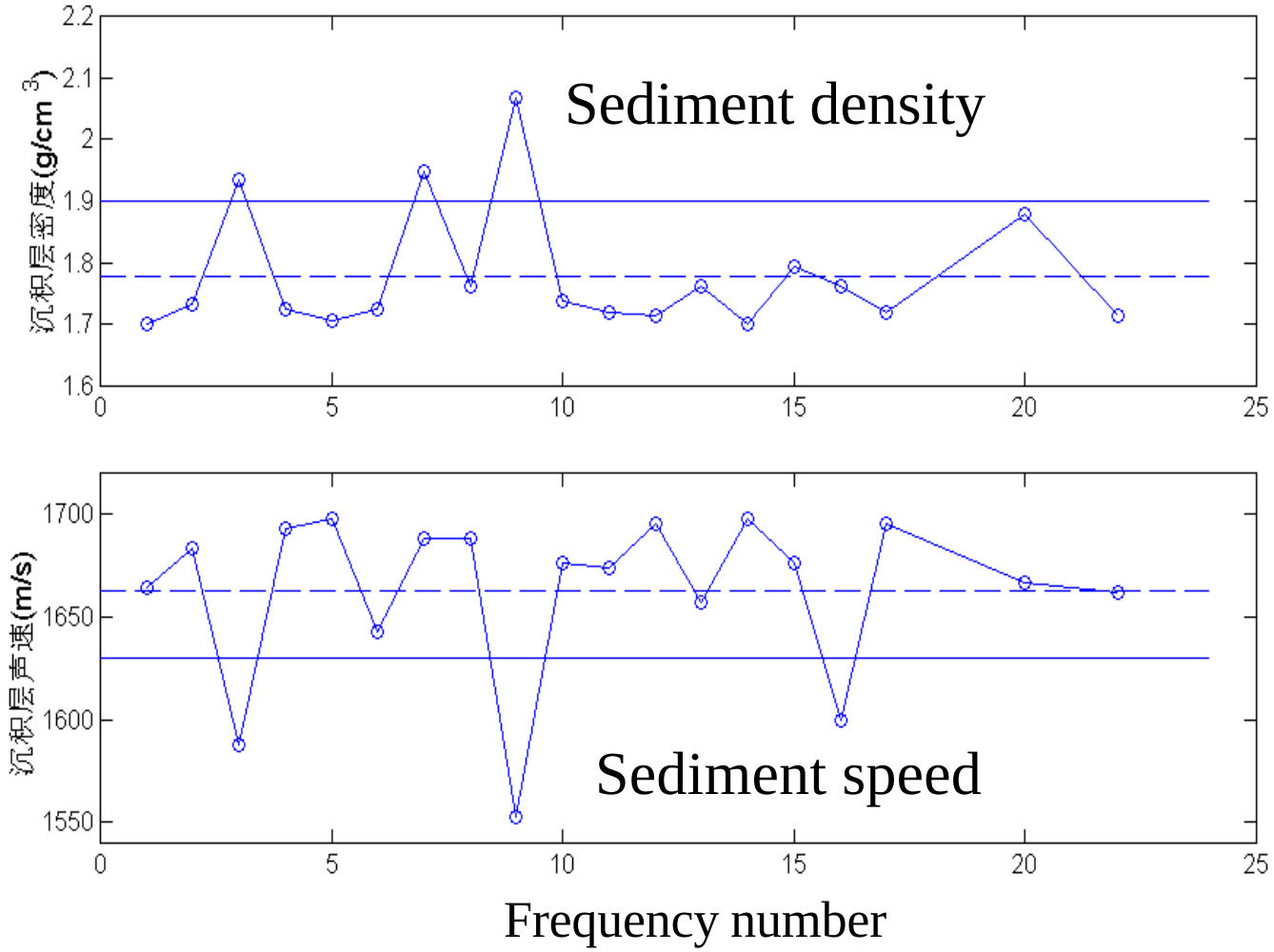
Multi-frequency direct Inversion (Shot10)



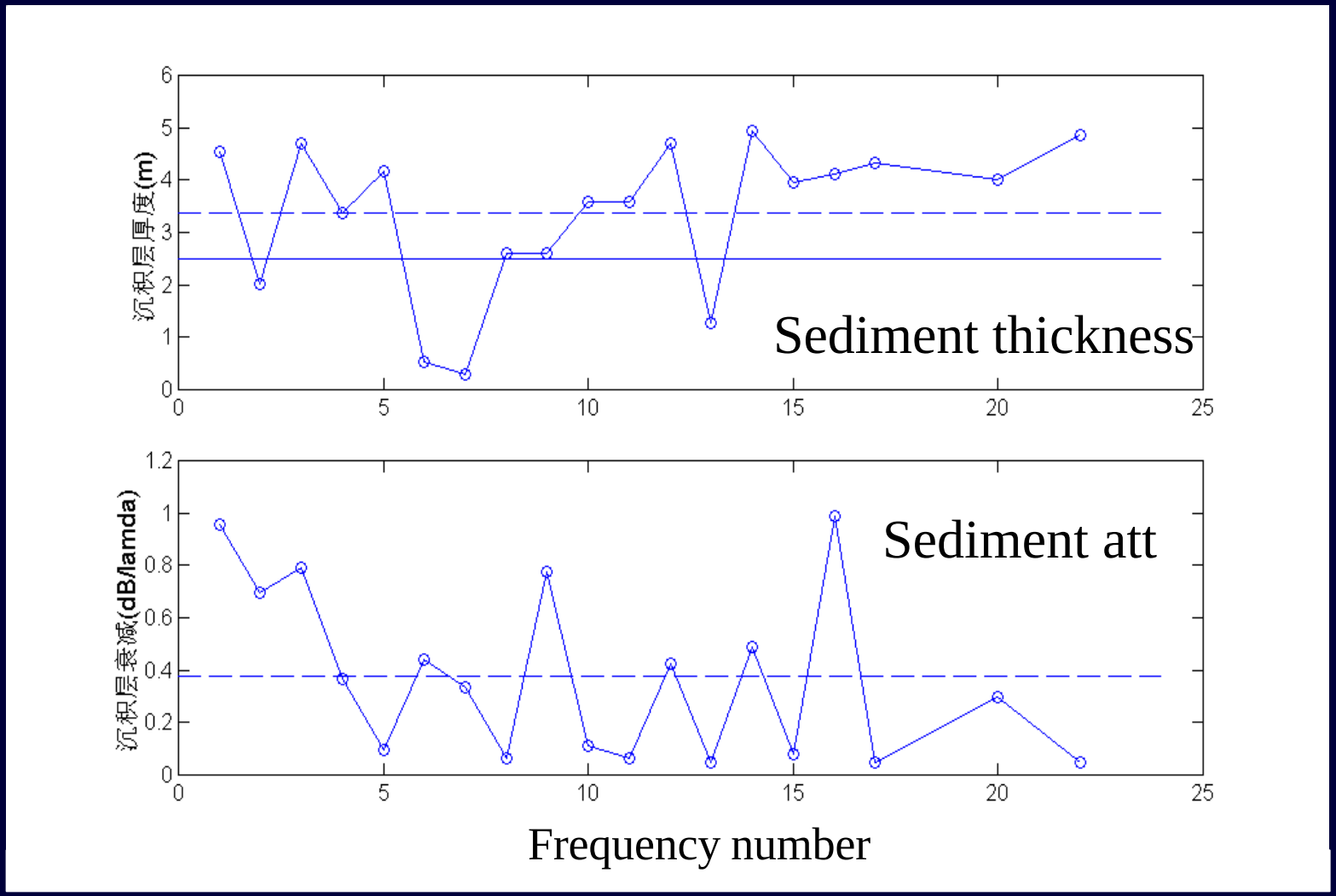
Multi-frequency direct Inversion (Shot10)



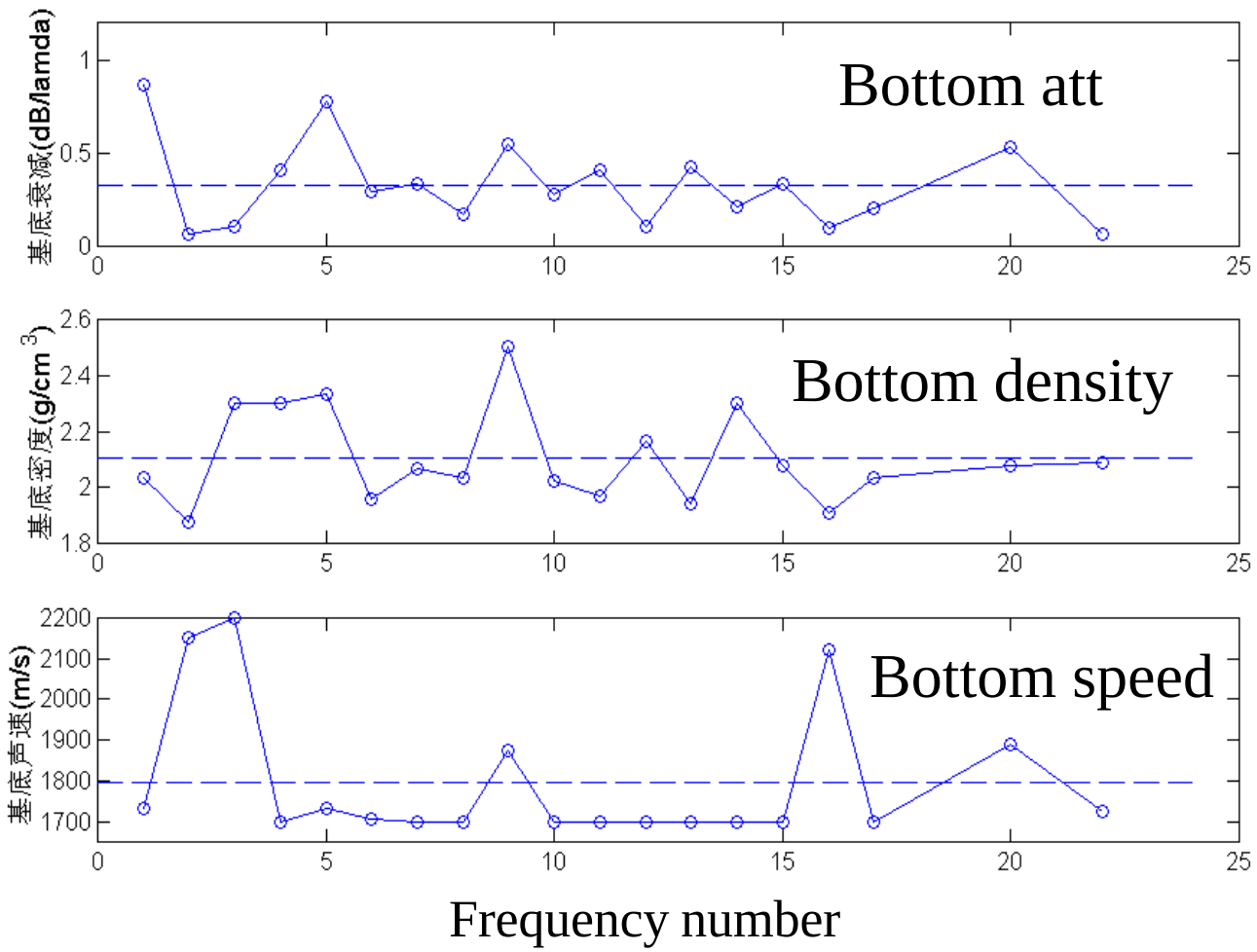
Multi-frequency direct Inversion (Shot10)



Multi-frequency direct Inversion (Shot10)

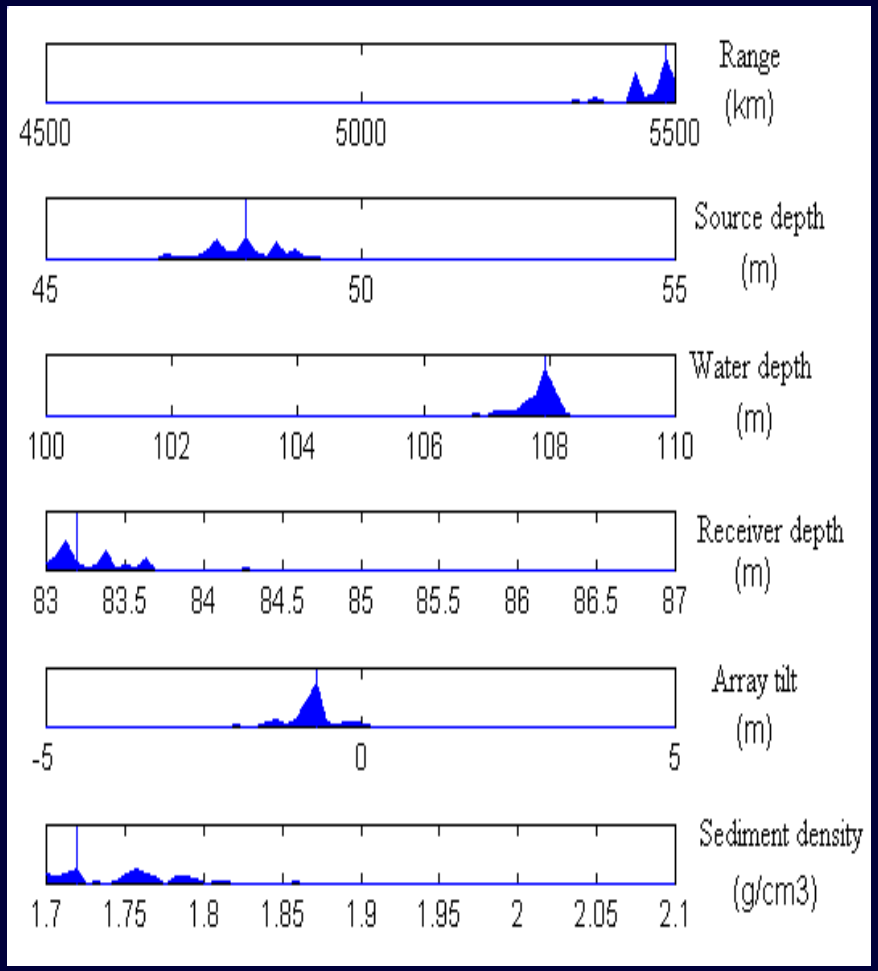


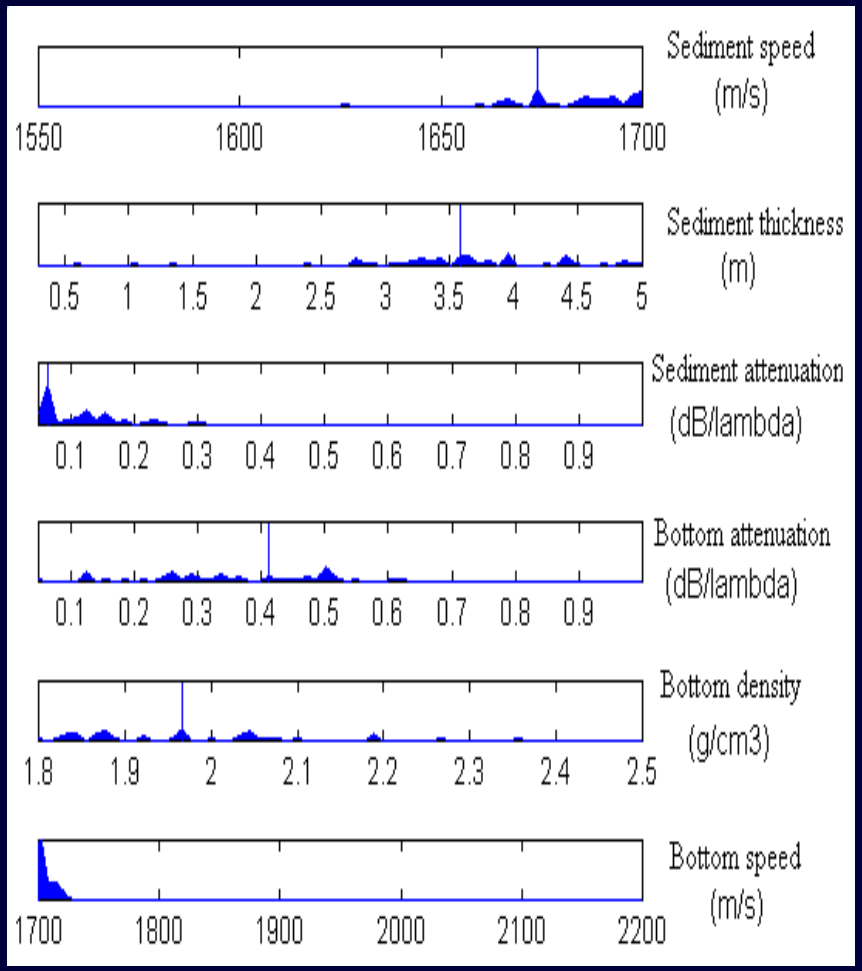
Multi-frequency direct Inversion (Shot10)



Inversion of typical shot data (Shot10)

A posteriori Probability distribution for the parameters

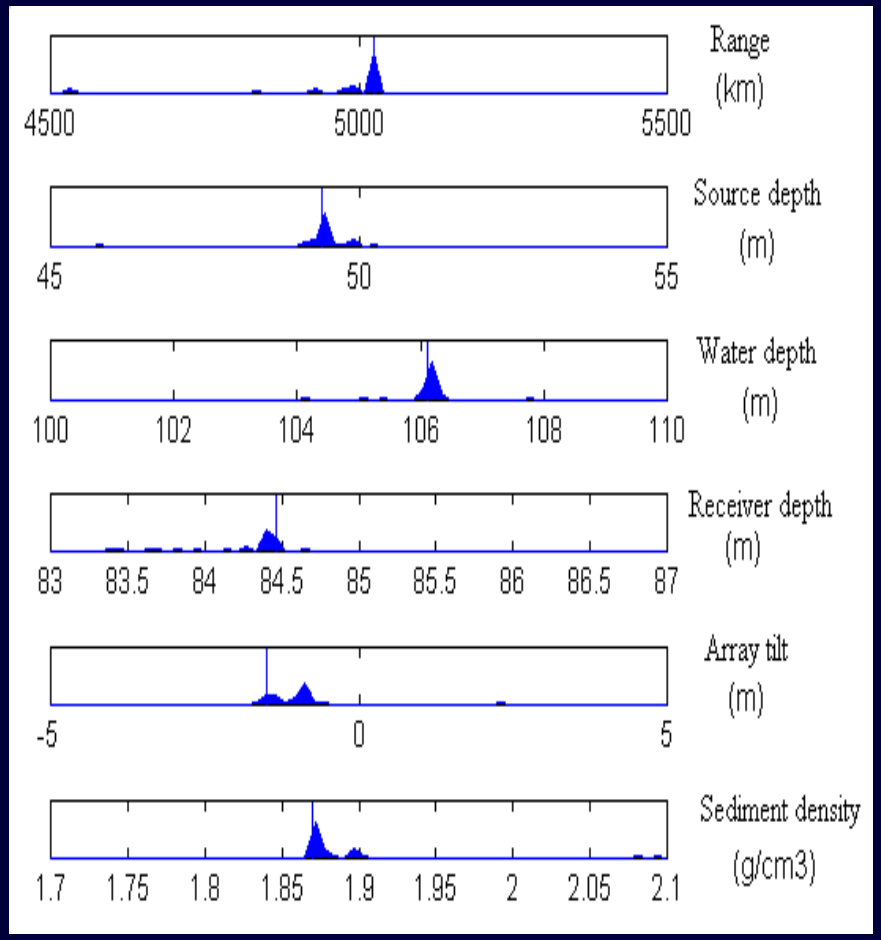


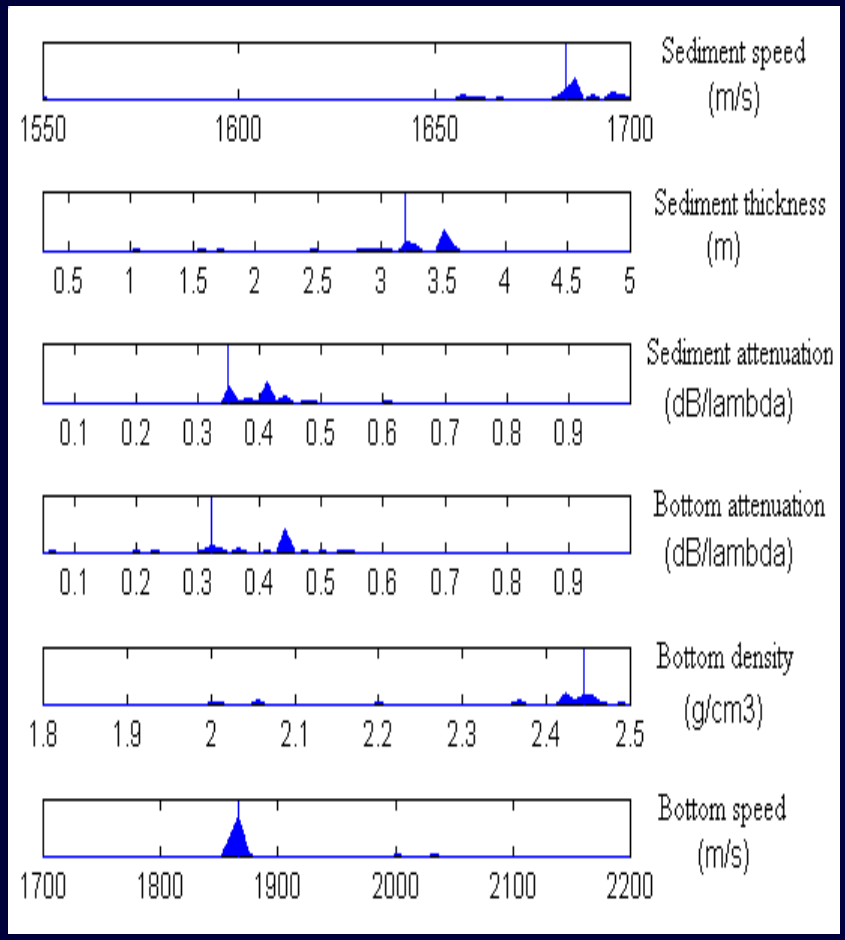


Direct all parameters inversion

Inversion of typical shot data (Shot10)

A posteriori Probability distribution for the parameters





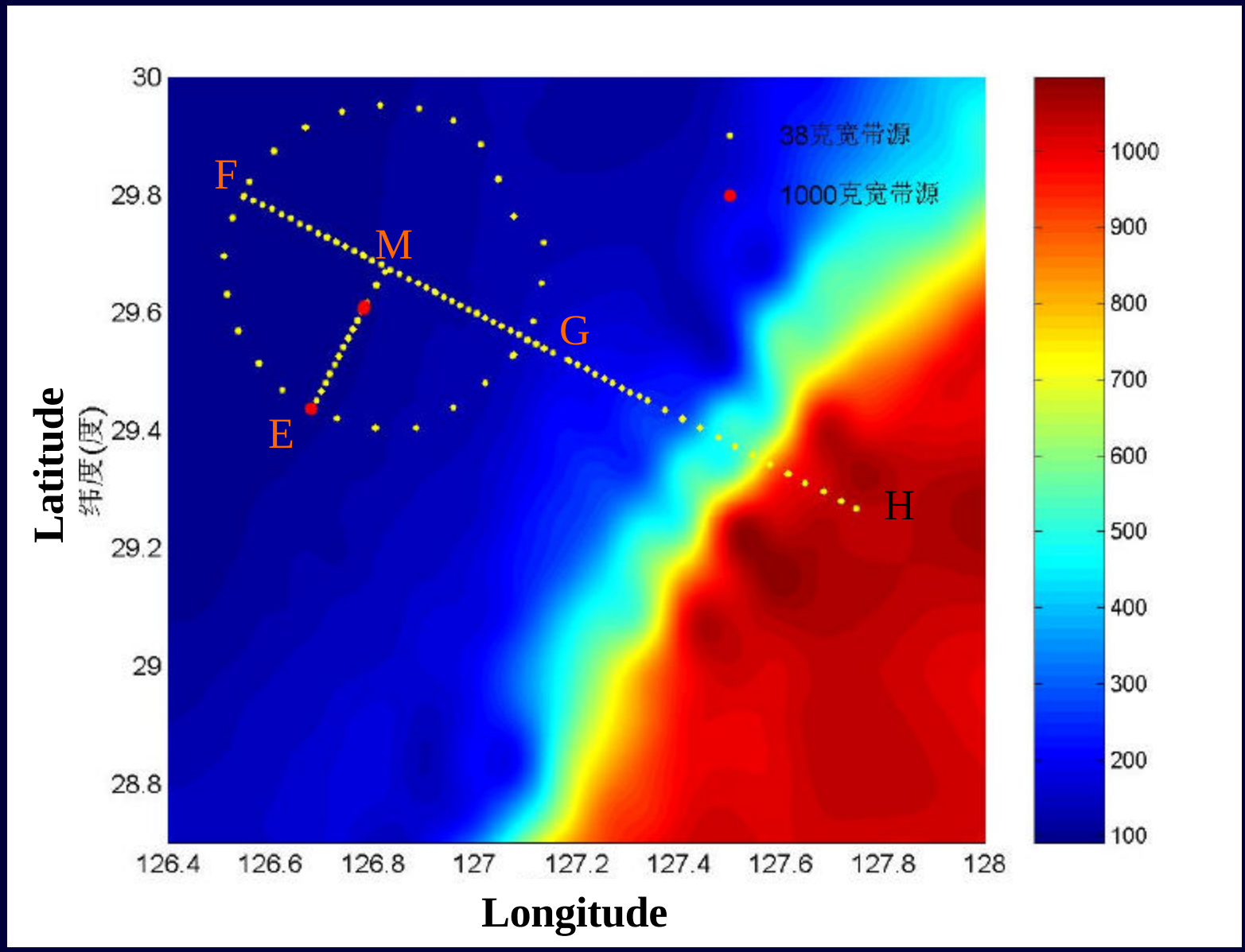
Multi-step inversion

Inversion of typical shot data (Shot10)

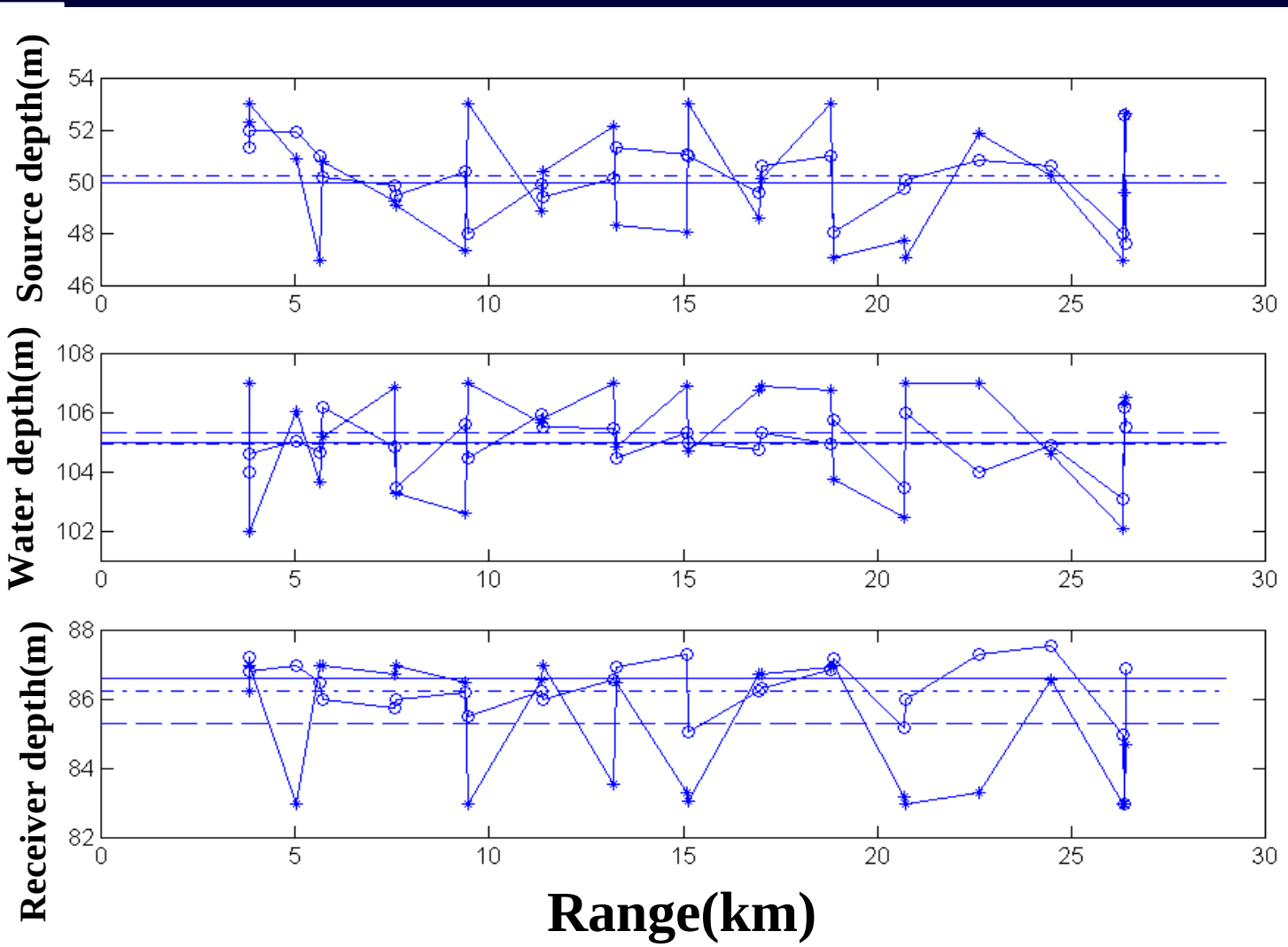
Compared with direct inversion

- Five geometric parameters: similar convergence probabilities
- Sediment speed, thickness and bottom speed: converged near the optimum values
- For the least four sensitive parameters:the global converging probabilities are increased
- Reason

Inversion of ME segment

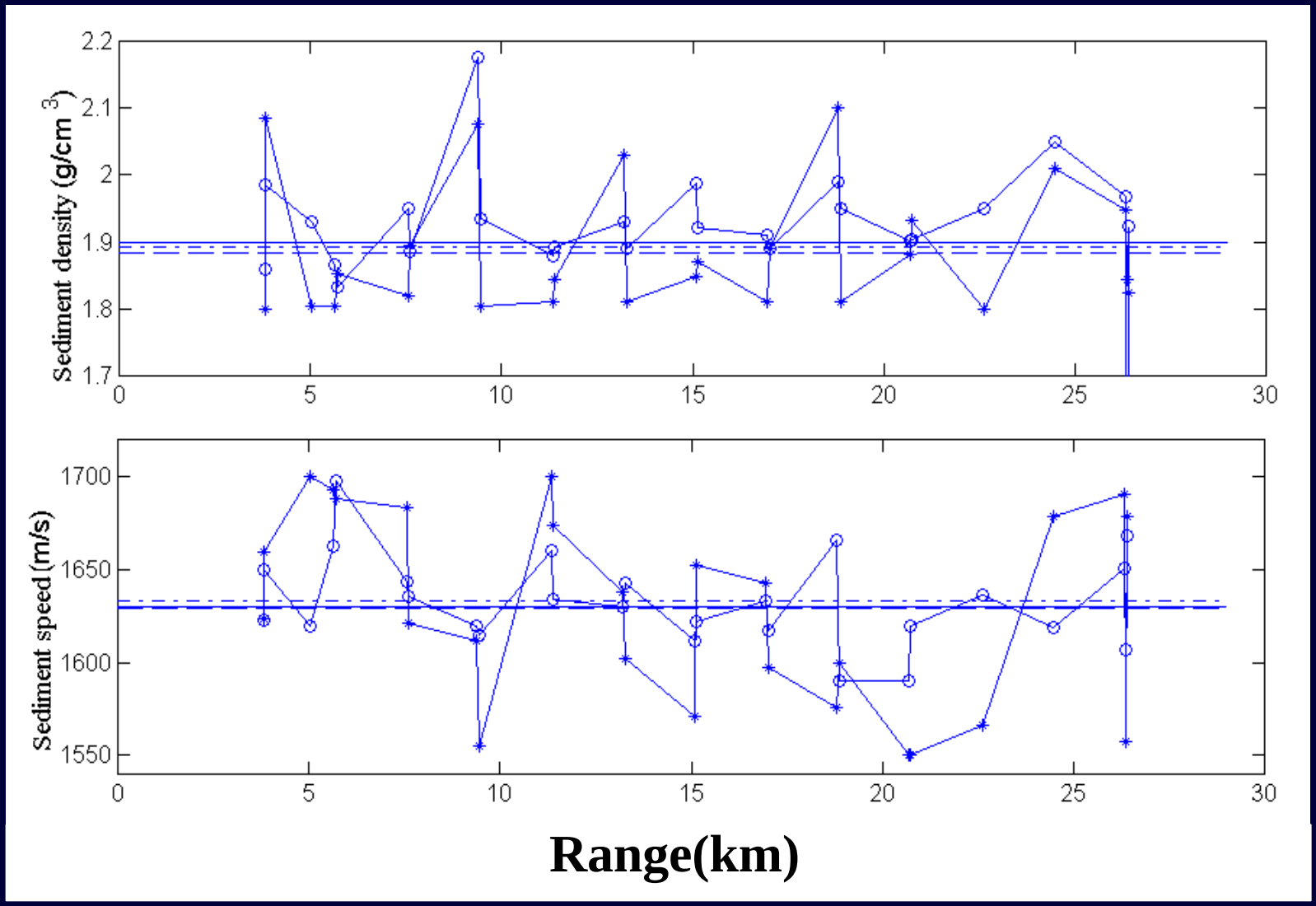


Inversion of ME segment



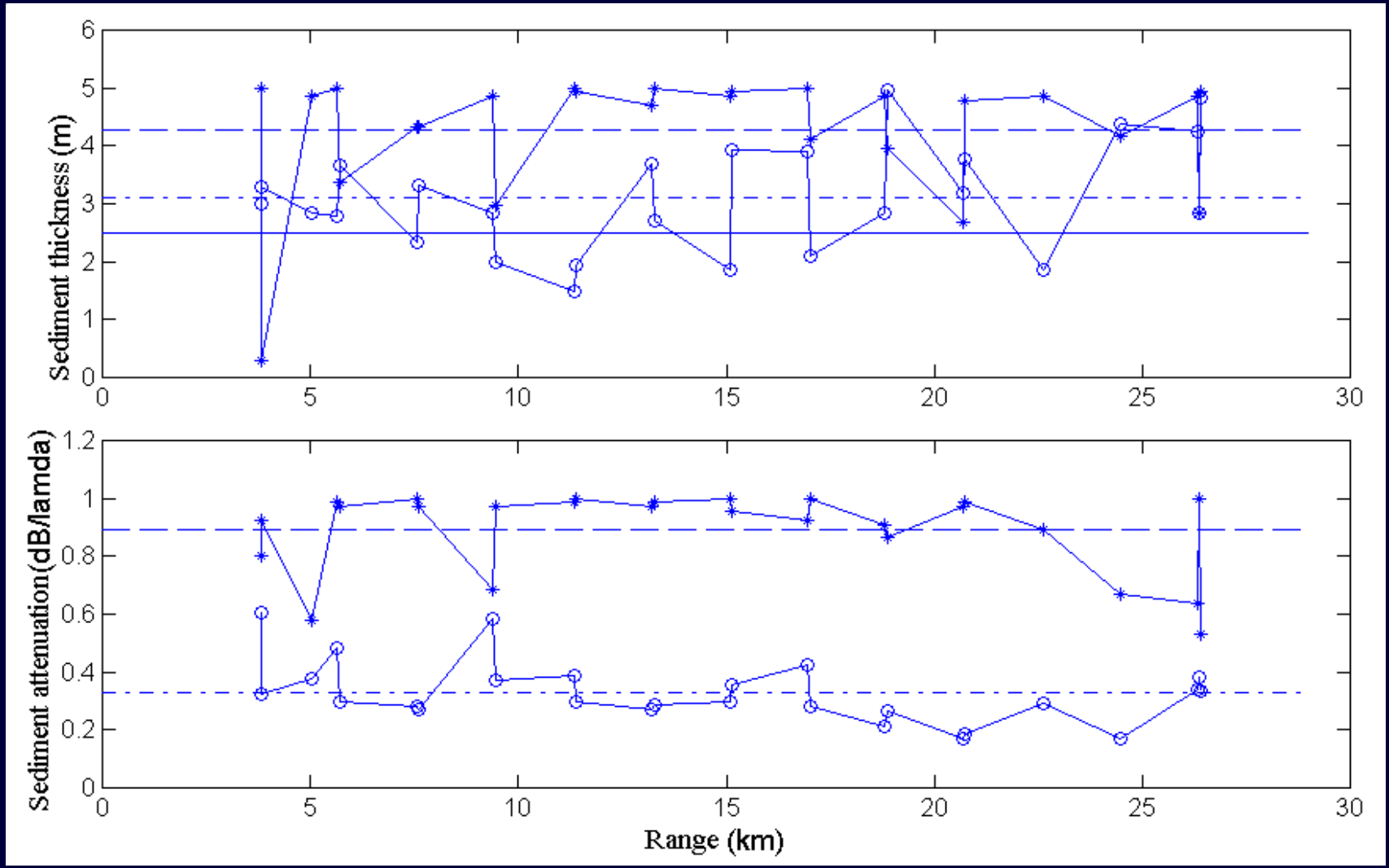
Geometric parameters

Inversion of ME segment



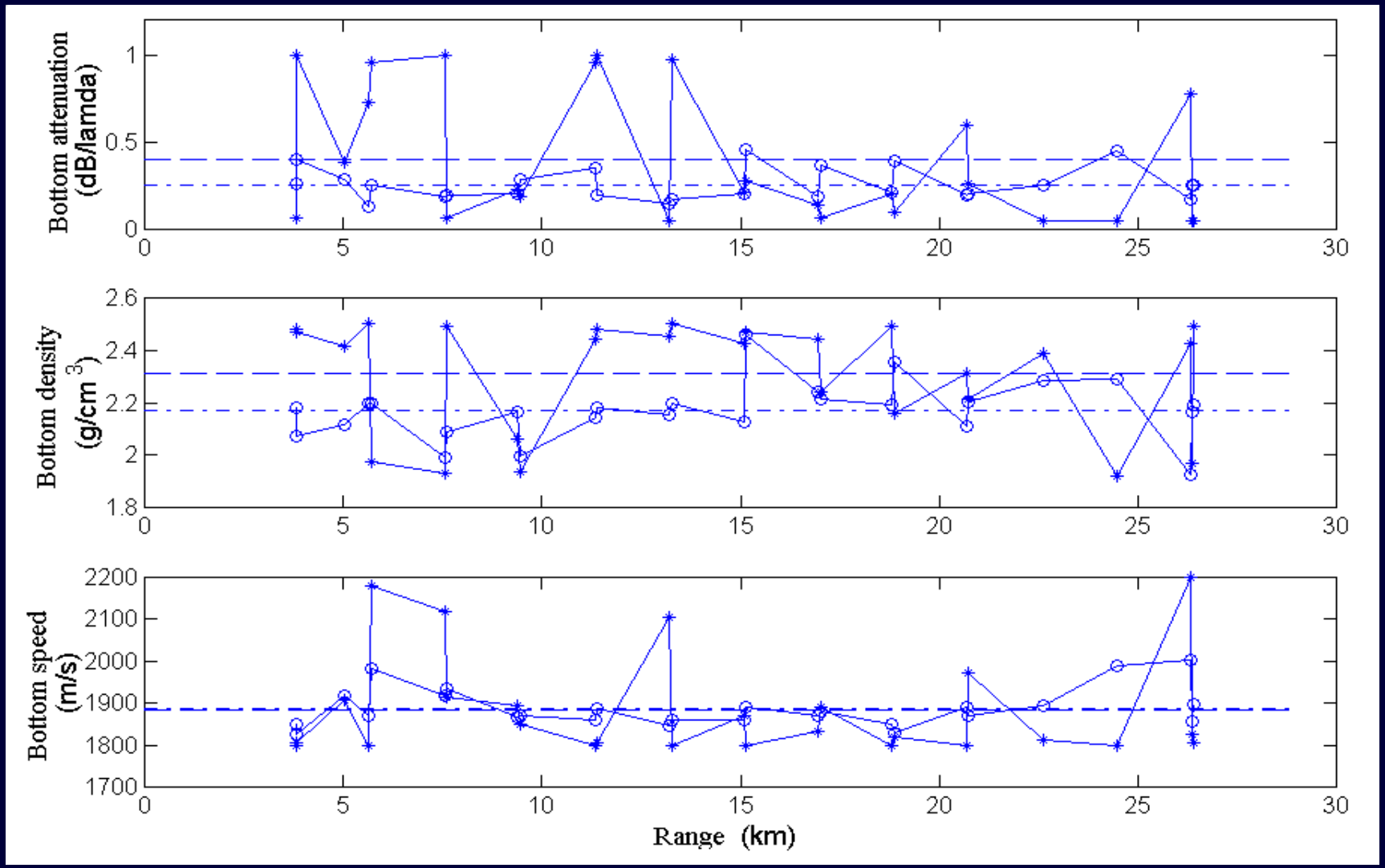
Sediment parameters (1)

Inversion of ME segment



Sediment parameters (2)

Inversion of ME segment



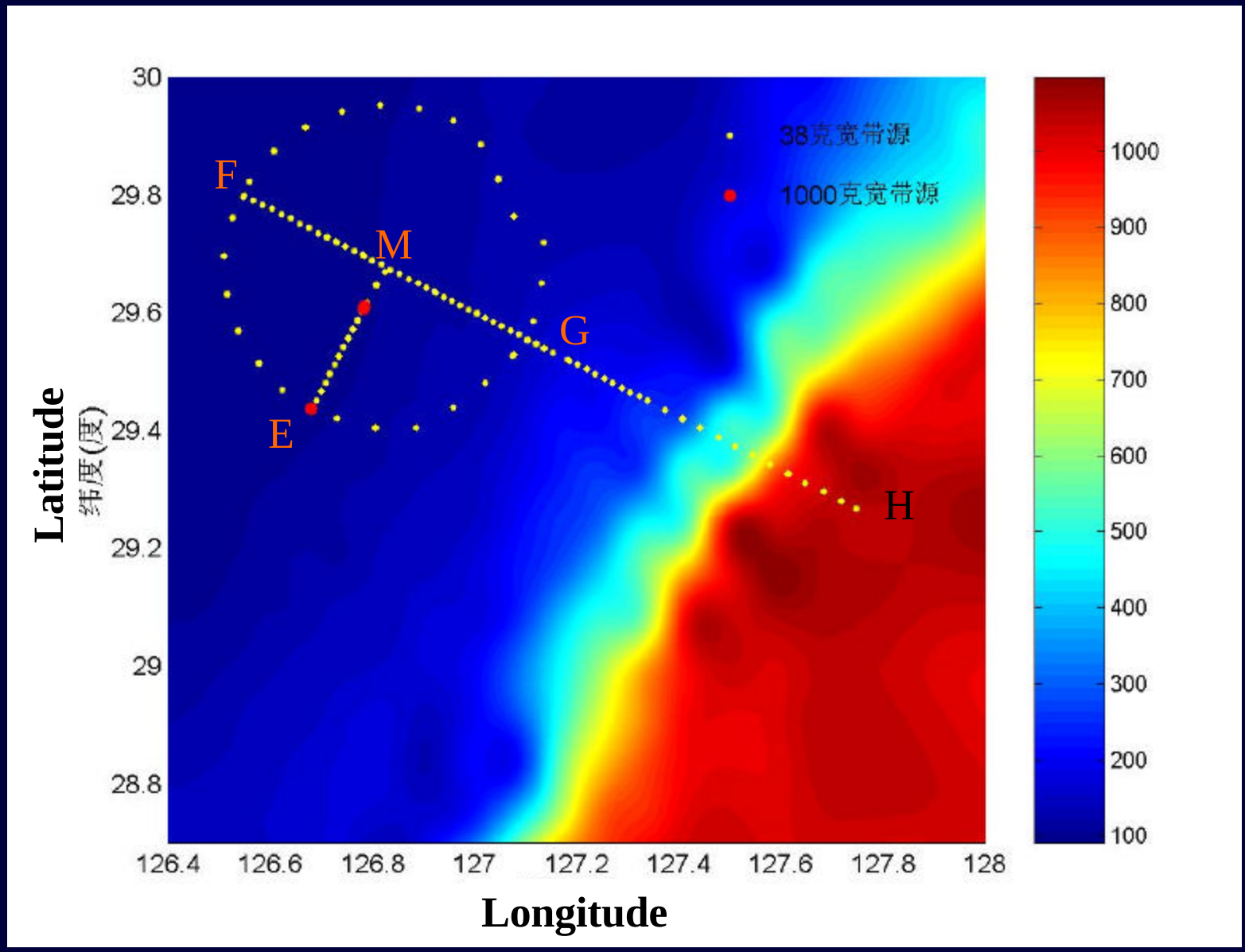
Bottom parameters

Inversion of ME segment

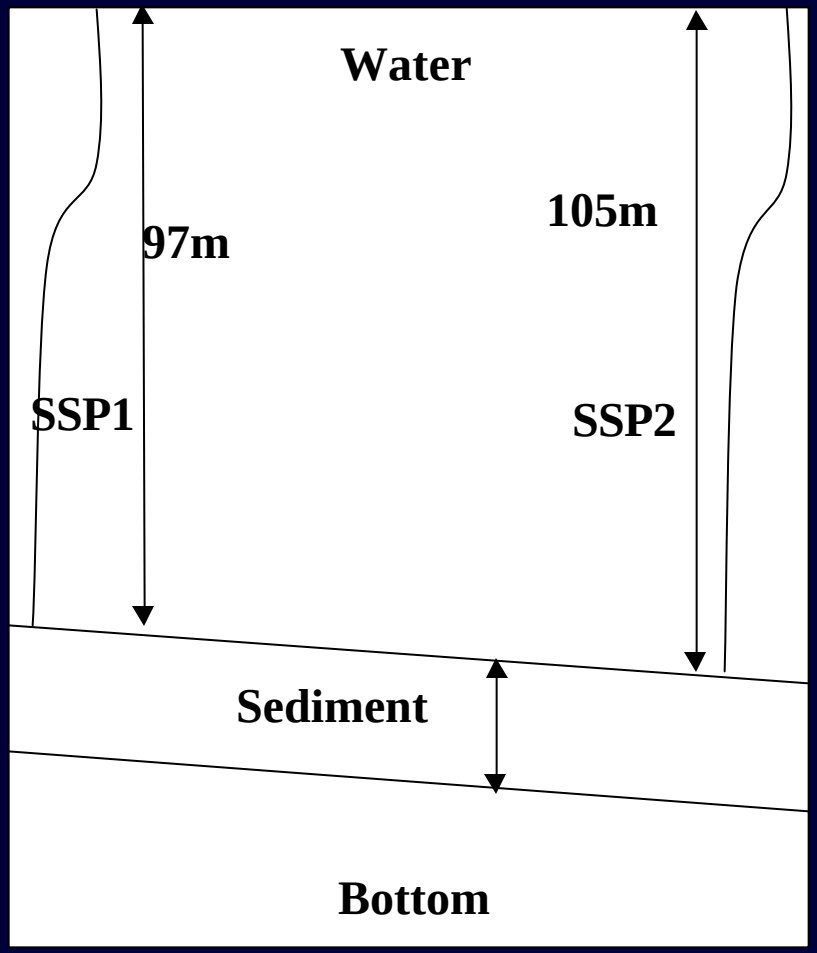
Geoacoustic inversion results in ME segment

Parameters		Shot10		ME segment	
		Direct inversion	Multi-step inversion	Direct inversion	Multi-step **inversion**
Sediment	thickness(m)	3.583	3.2	4.29	3.1
	Density(g/cm^3)	1.719	1.87	1.88	1.89
	speed(m/s)	1673.8	1683.3	1629.3	1629.9
	attenuation (dB/?)	0.065	0.35	0.89	0.33
Bottom	density(g/cm^3)	1.967	2.444	2.31	2.17
	speed(m/s)	1700	1866	1885	1887
	attenuation (dB/?)	0.412	0.321	0.4	0.256

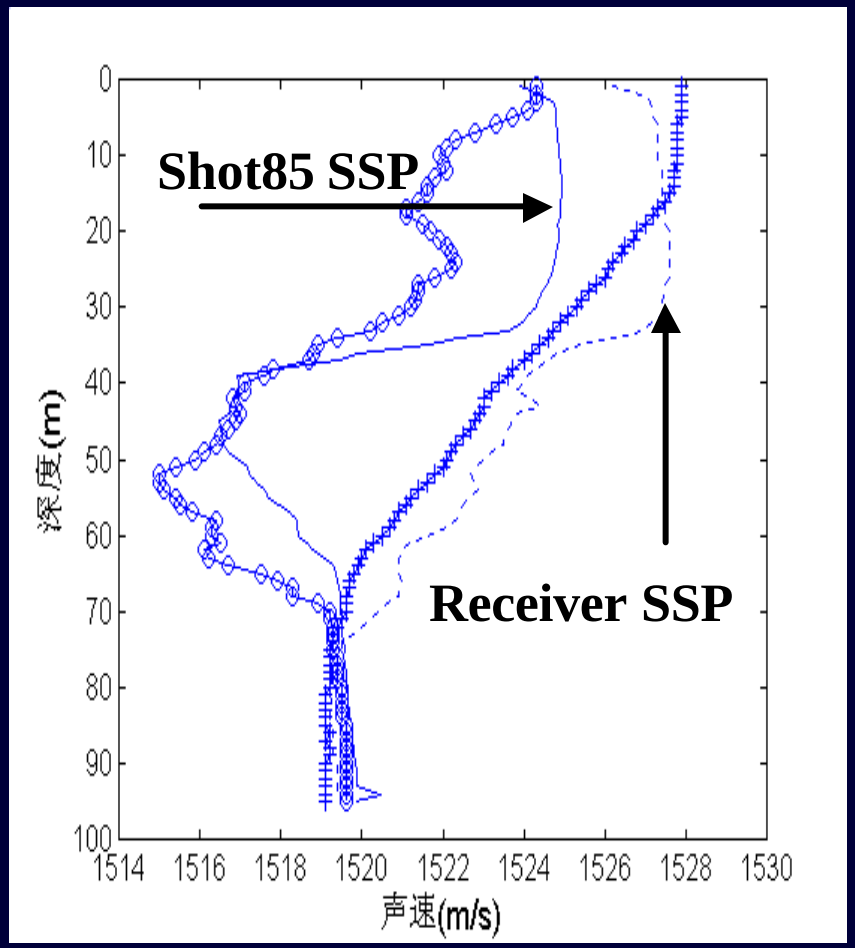
Inversion of NW portion (shot85)



Inversion of NW portion (shot85)

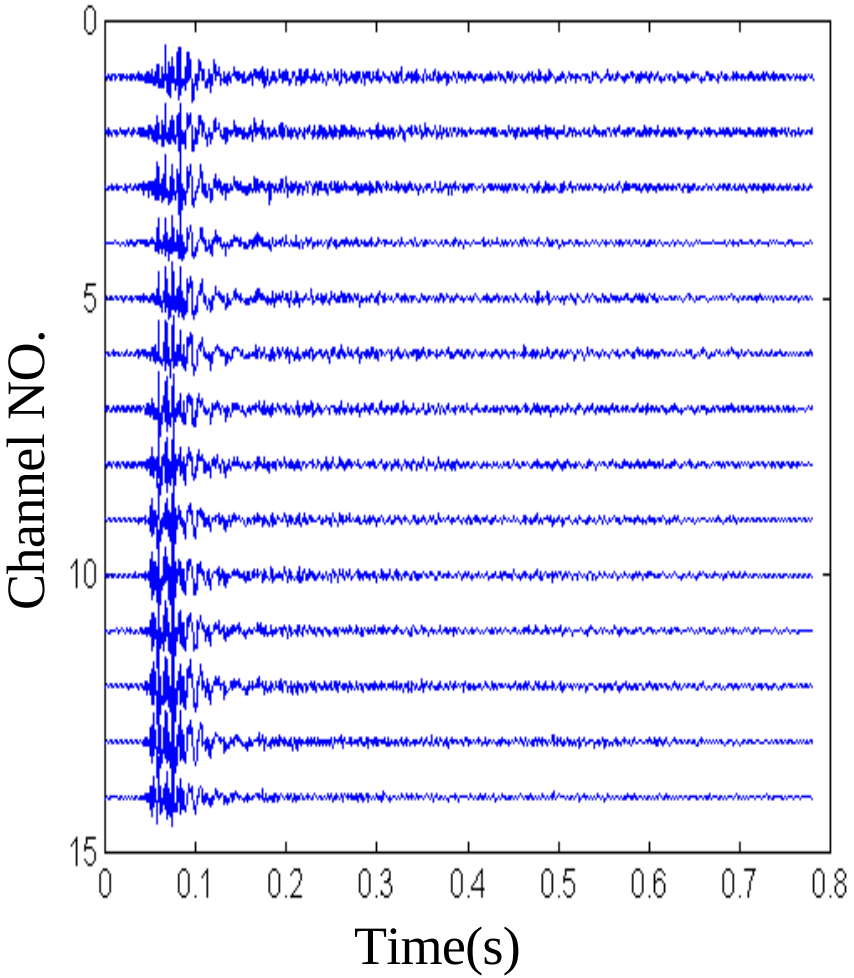


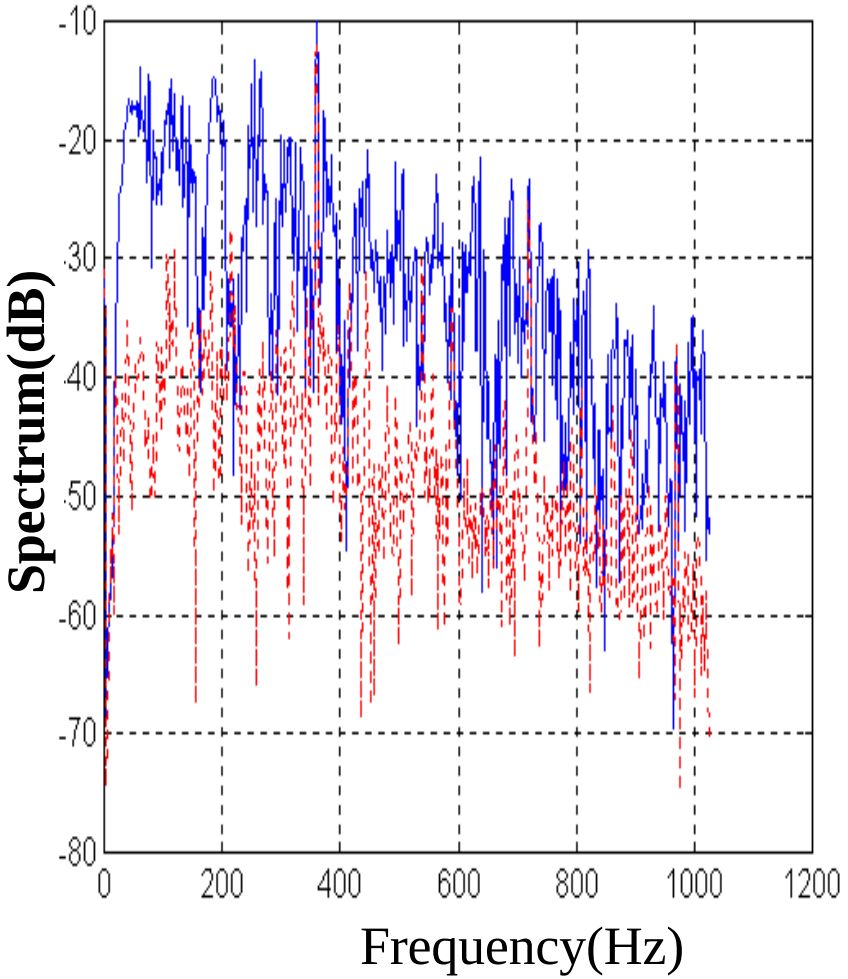
Parameters model



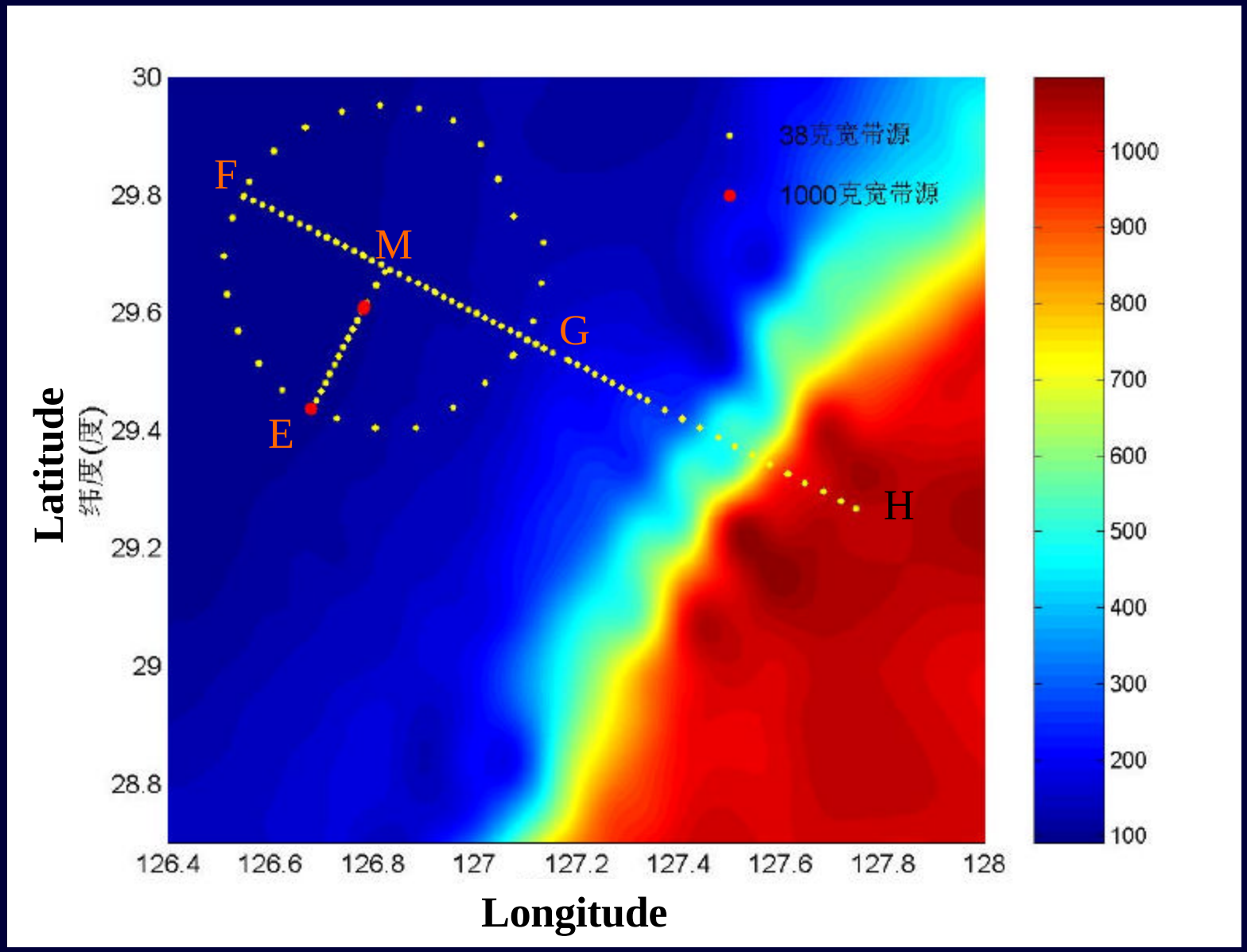
Sound speed profiles

Inversion of NW portion (shot85)

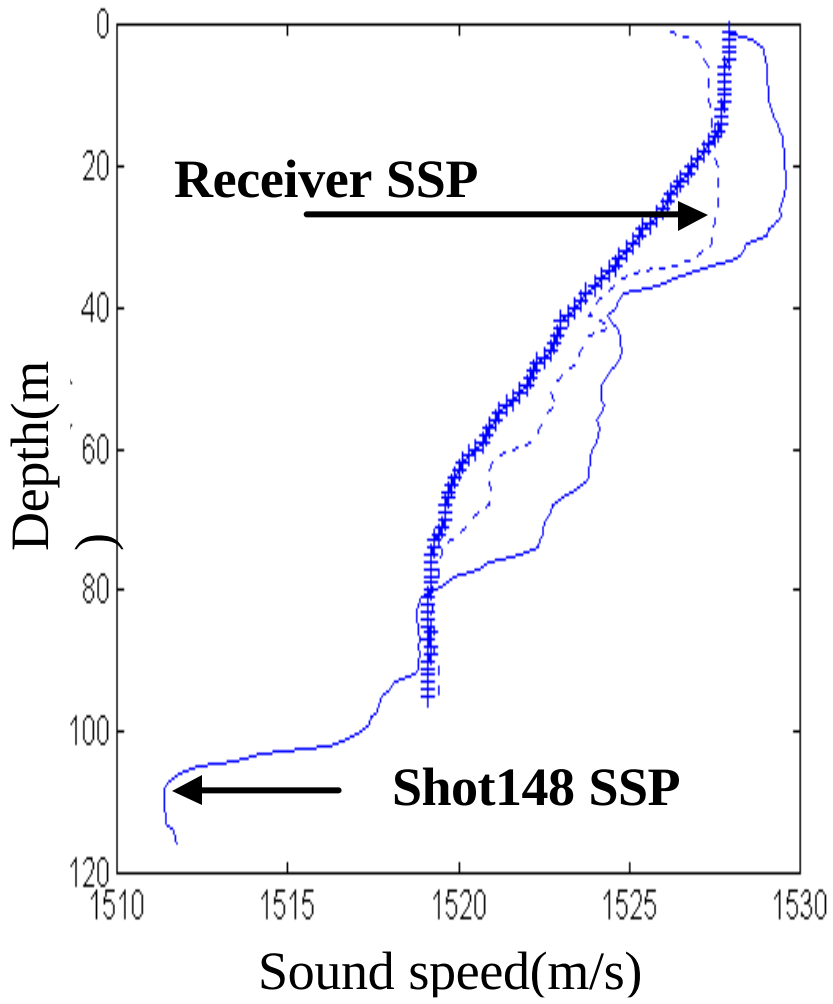


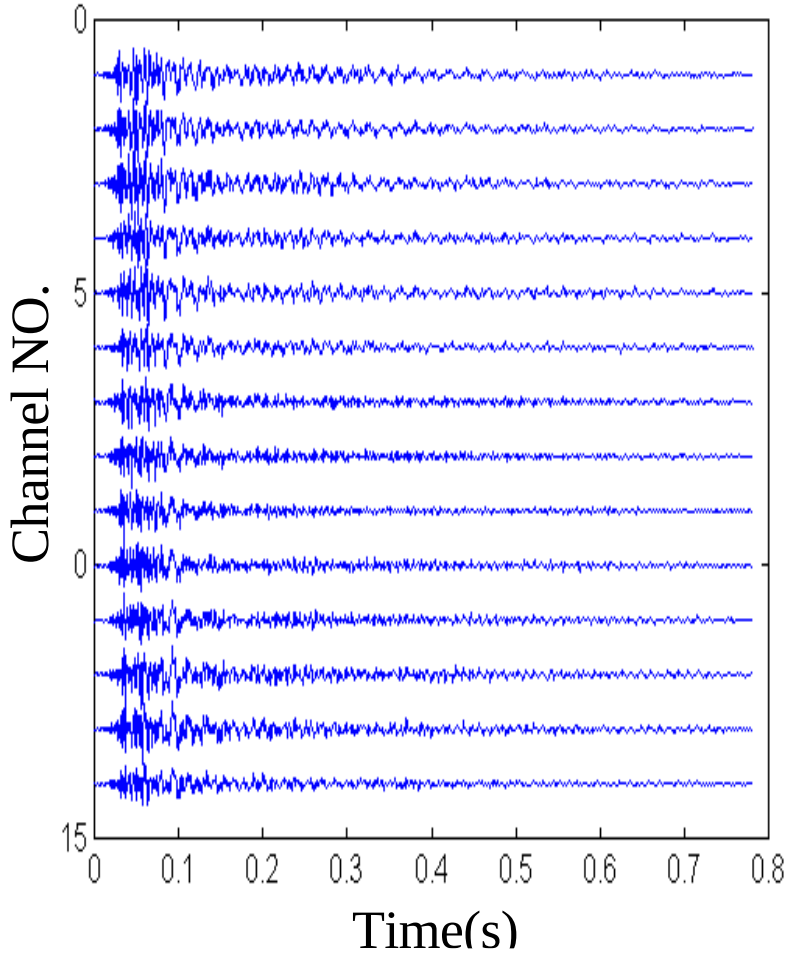


Inversion of SE portion (shot148)



Inversion of SE portion (shot148)





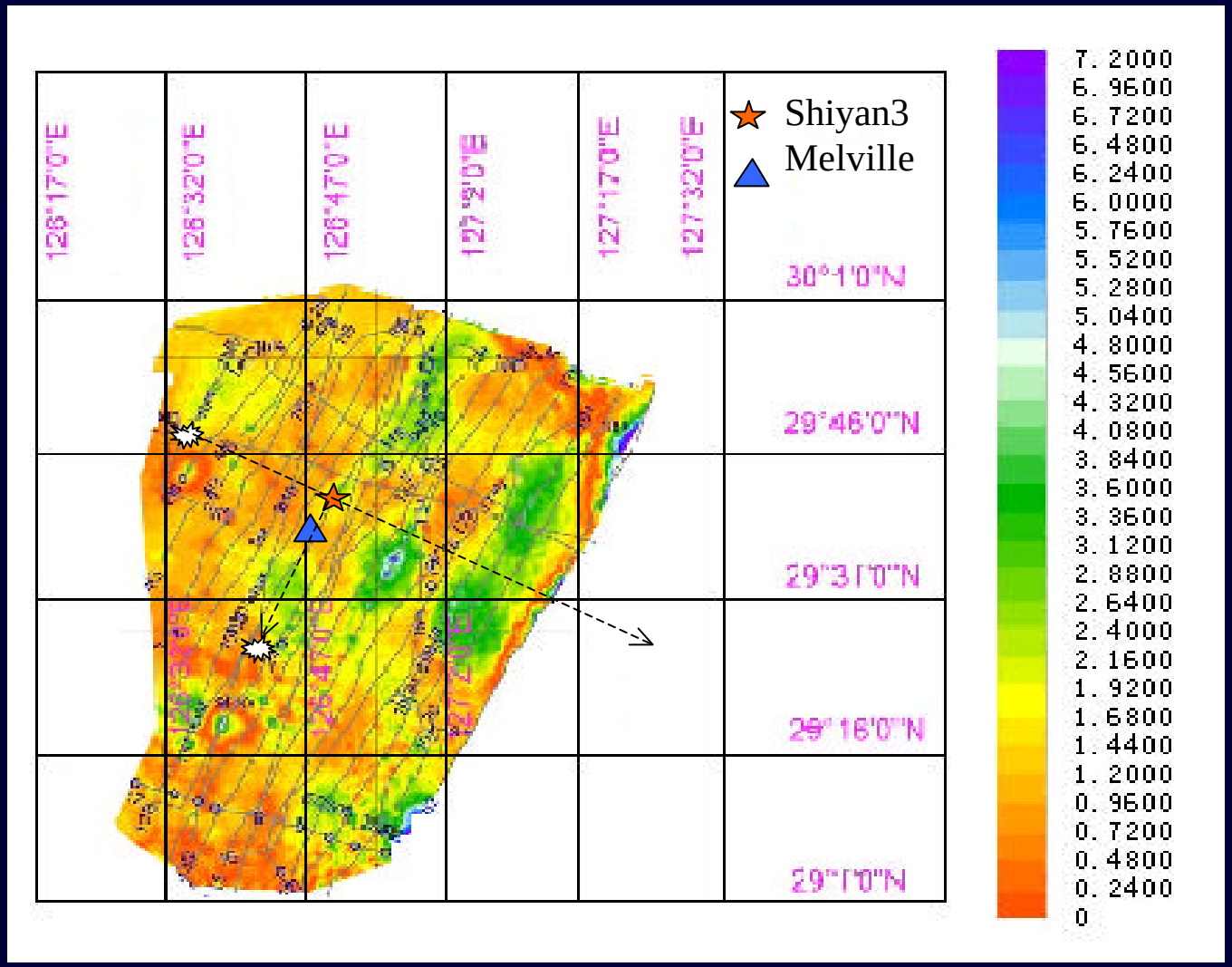
Geoacoustic inversion results of ECS

Parameters		Search space	NW (Shot85)	SE (Shot148)	SW (ME)
Sediment	thickness(m)	0~5.0	1.033	4.844	3.1
	density(g/cm^3)	1.7~2.1	1.82	1.92	1.89
	speed(m/s)	1500~1700	1594.4	1643.3	1629.9
	attenuation (dB/?)	0~1.0	0.425	0.32	0.33
Bottom	density(g/cm^3)	1.7~2.5	1.954	2.395	2.17
	speed(m/s)	1700~2200	1955.9	1803.7	1887
	attenuation (dB/?)	0~1.0	0.429	0.528	0.256

Comparison of inversion results for three local areas

* Sediment thickness
* Sediment density
* Sediment speed
* Sediment attenuation
* Bottom speed
* Others

Sediment thickness



From J.H.Miller and L.R.Bartek

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Thank you !